The

ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

VOL. XX No. 5 MAY, 1959

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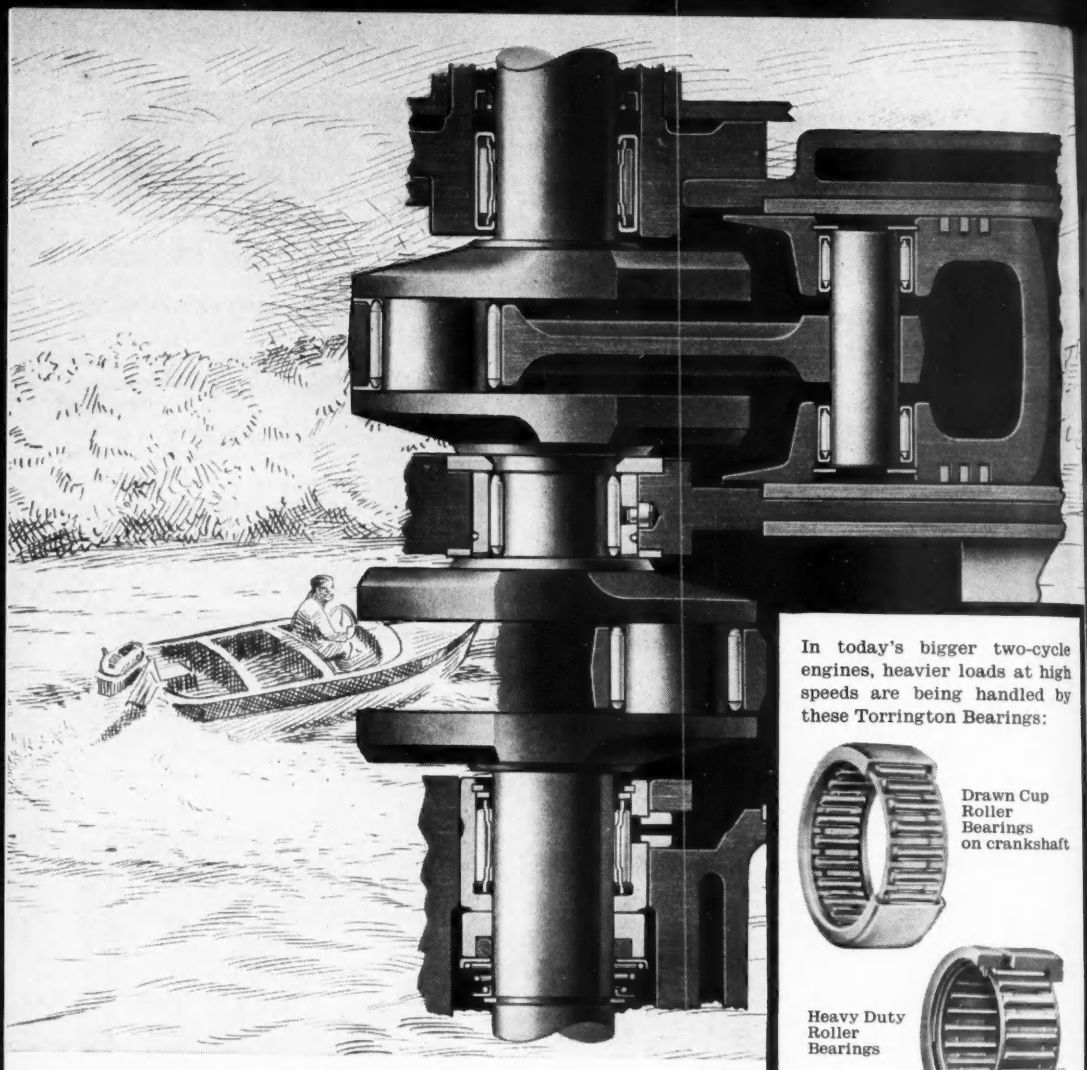

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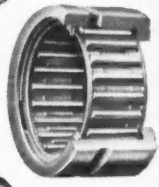
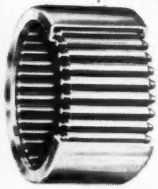


Heavy Duty Roller Bearings



Full Complement Needle Bearings on wrist pins

Needle Rollers with crankpin ends

Fractured outer race for centre main on crankshaft

THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

• *MEASURING THE FRICTION OF BALL BEARINGS*

A recent research report points out that, since the early experiments undertaken at the turn of the century, comparatively little has been published on the nature of ball-bearing friction and its quantitative values. In the past decade, however, progress in controls and instrumentation has resulted in a wider interest in the subject, and the lack of suitable data has created serious problems for many workers in this field. Several years ago, studies were initiated concerning the problem of standardizing friction-torque testing and the torque rating of anti-friction types of instrument bearings. These studies are now reported to include bearings such as those used in the gimbals of gyroscopic compasses, servo-systems, directional indicators, and various other indicating and control gyroscopes used in modern aircraft and guided missiles. A standard friction-torque method of testing has been developed, the basic principle of which is essentially simple. It employs a directly driven positioning system with a torque-sensing element incorporated in a restoring spring. Measurement of bearing friction is accomplished by slowly rotating the outer race of the bearing under test while the bearing is axially loaded. Frictional resistance between the races and the balls causes a torque to be applied to the inner race, winding the restoring spring through a certain angle. A strain gauge measures the resisting torque and provides a signal to a carrier amplifier, operating a chart recorder. In ball-bearing friction there is an infinite number of contact positions and an infinite number of coefficients of friction. Thus, the resisting torque is not seen as an average value, but rather as a continuous plot of irregular time-changing values.

• *EXPLOSIVE HARDENING OF MANGANESE-STEEL CASTINGS*

Manganese-steel castings can now be hardened by the blast produced by an explosive process which avoids the plastic deformation accompanying the conventional hardening processes of pressing or hammering. Moreover, it is claimed that the explosive method produces deeper hardening than that attainable by cold deformation of the newly cast part, or while it is in service. In the case of the explosive method, it is not the impact itself but the shock waves which do the work, these shock waves transforming the soft, ductile austenitic steel by stressing it internally and thereby making it strong, tough, and wear-resistant. The explosive-hardened product is claimed to be microscopically indistinguishable from the product hardened by conventional methods. A special explosive in sheet form has been developed for the purpose, this sheet being cut to shape by a knife and then hand-formed, so that it will conform to the shape of the surface to be hardened. This shaped charge is glued to the metal part and then detonated. Although simple in principle, explosive hardening should only be carried out by trained personnel, since the high-velocity shock waves produced are accompanied by high gas pressures, and these can be destructive, especially if confined, so much so that they can even destroy the part being hardened. If dimensional requirements are close, metal may have to be added to compensate for the slight distortion produced. While the process may be applied to many parts without distortion, some may require straightening after hardening. For closely machined tolerances, it is considered advisable to rough-machine first, and then to harden, followed by finish-grinding.

• *SEPARATION OF NON-FERROUS COATINGS FROM FERROUS METALS*

A recently patented process is concerned with the separation and recovery of lead-bearing copper-base alloys present as a coating on steel. Coatings of this type are encountered on steel scrap, to which the copper alloy adheres as a result of a casting, sintering, or electroplating operation. A typical example is a coating of this kind used as a liner on the steel backing structure of a bearing, and one application of the new process is directed to the recovery of the liner metal, using a special type of electrolytic bath, in which the steel is deprived of the non-ferrous coating, and the latter is then deposited on the cathode. Usually, the lead-bearing copper-base alloy to be separated and recovered contains at least 55% copper and between 1% and 40% lead, but separation and recovery of such a lead-bearing copper-base alloy also can be effected when the alloy contains up to about 10% nickel, 15% tin, and up to 10% zinc. Up to about 2% each of one or more additional non-ferrous metals can be included in the alloy without adversely affecting separation and recovery. Suit-

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able adjustments must, of course, be made in the composition of the electrolyte before adequate recovery of additional constituents of the lead-bearing copper alloy can be obtained. It is stated that the anode-to-cathode potential difference must be carefully controlled so as to maintain a potential drop of 0·8 V or less between the anodic scrap body and portions of the electrolyte in its vicinity. The total voltage drop across the cell will vary with the given conditions. The electrolyte used is of a strongly alkaline aqueous type containing an alkali metal cyanide and from 5 to 20 grams per litre of a tartrate radical.

• *IMPROVED THERMALLY ACTUATED PUMP*

A recent patent describes an improved thermally actuated pump or " thermopump ", without moving parts and capable of delivering a liquid under pressure. The pump comprises a system which includes a heated vapour-generating chamber in which some of the liquid to be pumped is evaporated, and a condenser for subsequently condensing the vapour. In operation, the vaporized liquid creates a pressure within the pump system and forces a portion of the liquid through a check valve. When the system is completely filled with vapour, owing to the expulsion of the liquid through the check valve, the vapour enters the condenser, where it is then condensed, causing a drop in pressure in the system. However, the liquid discharged from the pump system through the check valve cannot be drawn back into the pump system to restore equilibrium. With the system connected to a supply of liquid through a second check valve, the pressure reduction accompanying condensation will cause the system to refill through this second valve. In order to ensure regularity of operation, the thermopump condenser is arranged as part of a heat exchanger, in which the liquid to be pumped is utilized to cool the condenser wall, thus producing temperature stability and effecting very rapid or " shock " condensation of the vapour. It is claimed that, with such an arrangement, it has been found possible to produce a unit of materially reduced overall dimensions. Also, because of the rapid condensation obtained, a more speedy pumping action is achieved, and a rapid and powerful suction stroke is produced.

• *ACOUSTIC VIBRATION OF ATOMS*

A new method has been discovered of probing into crystalline structures by vibrating the atoms at frequencies up to 20 Mcs. For a considerable time the nuclear magnetic-resonance technique has been employed in the study of molecular structures, chemical processes, crystal structures, and other properties of matter. This method consists of placing a crystal in a steady magnetic field, so that the minute atomic magnets in the structure align themselves with the applied magnetic field. Another magnetic field, which varies with time and which is perpendicular to the steady field, is adjusted until its frequency equals that of the vibration of the minute nuclear magnets. Under this condition, the nuclear magnets absorb energy and thus produce electric signals which yield information regarding the nature of the structure under investigation. However, the nuclear magnetic-resonance technique is not applicable to metals or semiconductors, because these substances act as shields against magnetic fields. This drawback is circumvented by a new technique, in which an acoustic vibration is applied to the atoms, instead of a pulsating magnetic field, so that the molecules are vibrated mechanically. This vibration causes inside the structure electric and magnetic fields which resemble those produced by a pulsating field. If the acoustic vibration is adjusted so that its frequency is the same as that of the magnetic vibrators, the system behaves as it would under a magnetic field, except that the acoustic vibration is mechanical and the internal magnetic field produced is not hindered by the shielding effects of semiconductors or metals. It is therefore considered that this new technique will prove a useful tool for the investigation of the structures of electrically conductive materials.

• *SUPERCONDUCTING URANIUM COMPOUNDS*

It is well known that superconductivity occurs in various metals and alloys at very low temperatures. As the temperature of a superconductor is lowered towards absolute zero, its electrical resistance suddenly drops to about 10^{-12} of its normal value, so that electrical currents can then flow in the materials undiminished and practically for ever. In a recent investigation, measurements were made on uranium-molybdenum and uranium-niobium alloys which had been stabilized in crystal structure by heating to 1650°F for 24 hours and rapidly quenching in water. These alloys exhibited surprising temperature-resistance characteristics, inasmuch as, contrary to experience with all known alloys, their electrical resistance became progressively higher as the temperature was decreased towards one or two degrees above absolute zero, when they became superconductors. This superconductivity was especially surprising in view of the rise in electrical resistance preceding it. It is stated that correlation of the superconducting and resistivity data has thrown new light on the electronic structure of the atoms making up these alloys. Another study was concerned with the intermetallic compounds of uranium formed when uranium is combined chemically with metals such as aluminium manganese, iron, cobalt, and nickel. Among the intermetallic

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compounds containing cobalt, manganese, and iron, four hitherto undiscovered superconductors were found, two of them being the first superconducting compounds ever known to contain manganese and iron. Previously, the presence of either of these two elements was considered alien to the superconducting state, but this theory has now been proved false.

• *FLAME-RESISTANT POLYETHYLENE FOR WIRES AND CABLES*

Early attempts to impart a certain degree of flame resistance to polyethylene usually resulted in a considerable sacrifice of other inherently desirable characteristics of the material, either physical, electrical, or both. A number of years ago, systematic research was initiated with respect to formulations of polyethylene which would maintain a maximum of the original characteristics of the material, especially those which have a particular significance for insulation or jackets on wire and cable, and it was established that these objectives might be attainable if a so-called " adequate " or moderate degree of flame resistance was acceptable. Two tests were evolved for this purpose, one with regard to inflammability and the other with respect to the ability of the material to prevent or limit flame travel. It was also laid down that the original electrical characteristics of the polyethylene should not be affected beyond its ability to serve as a satisfactory insulator in the power and audio-frequency spectrum, with minimum reduction in its original and aged physical properties, moisture resistance, weathering, low-temperature characteristics, and resistance to thermal or environmental stress-cracking. As a result of these investigations, it has now been found that loadings on polyethylene up to 36%, with proper ratios of chlorinated paraffin to antimony trioxide, produce wire-coating compounds which meet the desired levels of flame retardancy specified. The use of polyethylene of high molecular weight improves the physical characteristics of the resultant mixture, while the addition of small quantities of butyl rubber, up to about 5%, further improves the properties, so that the final compound produced more closely exhibits the original performance characteristics of the polyethylene resin. These compositions are reported to constitute satisfactory insulation and jacket compounds.

• *CONTROL OF LIQUID-METAL FLOW IN CONTINUOUS CASTING*

Precision control of the liquid metal used in continuous casting processes is a perennial problem, as the handling of liquid metals with a high melting point, e.g., 3200°F, is particularly difficult. In a recent study the advantages of using magnetic force as an effective method of control have been investigated, the specific problem being the development of a means of precise control of liquid steel to a rolling mill making welding rods directly from the molten metal. After a study of more conventional control methods, several techniques were ruled out, including pouring directly from a ladle onto the rollers forming the rods, the use of a ladle equipped with a stopper rod, and control by cooling the nozzle with water. Attention was then directed towards the use of a magnetic field moving parallel to a tube to control the flow of metal inside the tube, the field acting simultaneously as a pump and a heater. The problem of finding a material that would stand up to liquid steel was also investigated. Ceramics, oxides, carbides, silicides, and borides were found to be quickly attacked, but sintered alumina was found to be sufficiently resistant to the molten steel. The tube in which the metal is magnetically controlled is made of Inconel with a sintered alumina liner. The iron and coils surrounding the tube and supplying the magnetic pumping action are cooled by forced air. To prevent cooling of the metal, the tube itself is electrically heated to about 2100°F. This laboratory installation has proved the effectiveness of the magnetic technique for controlling the flow of liquid metals. However, the apparatus cannot as yet instantaneously and absolutely stop the flow of metals, and further development is required.

• *NEW MAGNESIUM SHEET ALLOY*

As distinct from conventional magnesium sheet alloys, which usually require stress-relief after welding to prevent stress-corrosion cracking, a new magnesium alloy has now been developed for room-temperature service and does not need post-weld treatment. This alloy, which contains 1·0 to 1·5% zirconium and 0·12 to 0·22% rare earths, is reported to have good weldability and formability. The material is normally supplied with a mill finish, but it is also available in the pickled condition or with a mill prime surface. The fact that this alloy does not require stress relief after welding should make it a suitable material for use in very large structures and in site repair work. Proposed applications include storage containers, shipping containers for commercial bulk products, and tank-trailer bodies. The new alloy is generally comparable with a conventional room-temperature sheet alloy containing 2·5 to 3·5% aluminium, 0·6 to 1·4% zirconium, and a minimum of 0·2% manganese, and is claimed to possess the highest toughness of any magnesium sheet available. Thus, the energy required to fracture a sheet with either impact or static loading is given as 120 to 150% that of the conventional alloy. The fatigue properties of the two alloys

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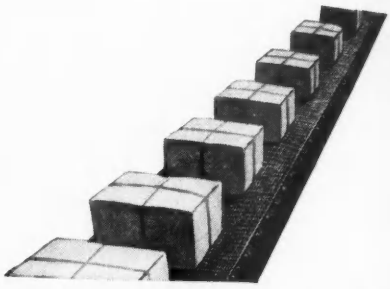

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are stated to be equal, as are also the machining characteristics and the general corrosion resistance, although the new alloy is more susceptible to pitting attack in 3% sodium chloride at 95°F. Measurements of the loss in tensile strength due to exposure indicate that both alloys have equivalent atmospheric corrosion resistance.

• *WROUGHT IRON WITH IMPROVED PROPERTIES*

An improved wrought iron is claimed to have superior corrosion resistance, owing to increased deoxidation of the base metal, in conjunction with an increase in phosphorus content and a change in the composition of the iron silicate, which is highly resistant to attack, serves as a barrier to pitting, and disperses the corrosive action evenly over adjacent areas. The silicate inclusions also act as a bond for the corrosion products as they are formed, thus protecting the underlying metal from further attack. In this way, corrosion resistance is increased by at least 25% over that of conventional wrought iron. Wrought iron shows its greatest advantage over carbon steels in heat-transfer equipment handling brines, industrial cooling waters, and industrial flue gases. It is unaffected by refrigerating gases such as ammonia, carbon dioxide, and freon. The new wrought iron, which is available both as pipe and in various flat products, can be readily formed hot or cold by the same procedures as those followed in the working of mild carbon steel but, for forging, higher temperatures are required. However, the low carbon content is claimed to minimize any tendency to burning. Welding can be carried out by hammering, by oxyacetylene, and by all conventional arc methods, the silicate inclusions acting as fluxes. Because of its low residual and low total metalloid content, especially with respect to manganese and carbon, the material can be used for nuclear shielding, without distorting radiation measurements in reactor instrumentation.

• *CASTING WITH THE USE OF EXOTHERMIC MATERIALS*

It is well known that, in the production of castings, particularly in the case of ingots, it is necessary to maintain the ingot feed-head in a molten condition, so that the molten metal will feed the body of the ingot in proportion as the ingot solidifies and shrinks. In order to prolong the liquid condition in the ingot feed-head, use can be made of insulating refractory linings or of exothermic linings, which, however, suffer from the disadvantage that combustion of the exothermic material starts well before the moment when it would be useful, and/or ends after the period for which it is required. An improved, recently patented method of casting provides in the feed-head a lining which comprises a number of shaped fabricated elements, each of which comprises a layer of an exothermic product, i.e., one which includes an oxidizable material and an oxidizing substance, and a layer of heat-insulating material facing the interior of the mould for the purpose of delaying combustion of the exothermic product until the metal of the mould begins to solidify. In this way, the latent heat of the metal constituting the feed-head is transmitted only to the exothermic material through the mass of insulation material, which preferably consists of agglomerated moulding sand. The period of time at the end of which the combustion of the exothermic product will commence is therefore a function of the nature and especially of the coefficient of heat conductivity of the agglomerated moulding sand and of its thickness, so that this period can be made independent of the properties of the exothermic product itself.

• *SYNCHRONIZATION OF POLYPHASE INDUCTION-MOTOR SYSTEMS*

In driving systems comprising at least two asynchronous polyphase induction motors with slip-ring rotors, a conventional method of achieving synchronism is to connect the rotor or stator windings directly to the mains and to interpose a frequency-changer, driven by an asynchronous polyphase induction motor and not mechanically coupled to either of the driving motors, between the slip-frequency network and the mains. A system of this type has, however, certain disadvantages. Thus, as the energy of the motor driving the frequency-changer is not taken from the slip-frequency network, the system is inclined to hunt. Also, the frequency-changer is a polyphase commutator machine with slip-rings, whose dimensions increase considerably with the regulating range required, so that it may be necessary to use specially designed machines, with a possibly prohibitive increase in the cost of the installation. According to a recently patented system, however, these disadvantages can be overcome if the asynchronous motor is connected to the slip-frequency network and is coupled by a mechanical transmission to the frequency-changer, which is constructed as a polyphase induction motor with a slip-ring rotor. As a result, the system consists entirely of parts which are easily available. The asynchronous polyphase induction motor driving the frequency-changer can be constructed as a motor with a slip-ring rotor and can be furnished with a short-circuitable starting resistance.

For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.

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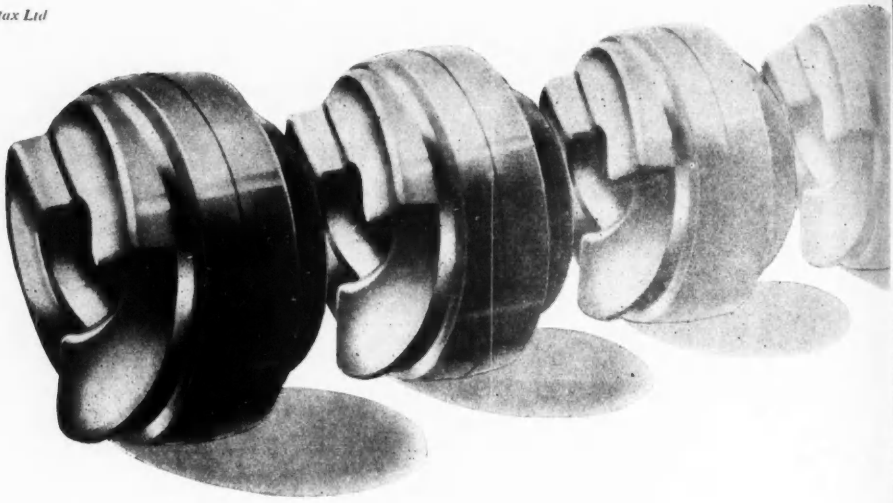

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European Developments in Experimental Stress Analysis

By M. L. MEYER, B.SC.(ENG.)*

THE Stress Analysis Group of the Institute of Physics (Great Britain), in collaboration with the Instituut T.N.O. voor Werktuigkundige Constructies (Holland), recently held a conference on Stress Analysis at Delft. Members from fifteen nations attended, and four papers gave surveys of stress analysis in France, Germany, Holland, and Great Britain, while fifty-two special technical papers were discussed. The papers and any substantial contributions to the discussions will eventually be published in a volume of proceedings.

The present report is intended to summarize some of the more interesting developments mentioned at this conference, and is based not only on the actual proceedings, but also on personal observations and discussions by the author.

For convenience, the report has been divided into three sections, i.e., methods of strain or stress measurement, applications (mainly in the field of civil and structural engineering), and instrumentation. Obviously, however, these sections will overlap to some extent, especially where methods of applications depend on new or improved instruments.

METHODS OF MEASUREMENT

Hickson (Great Britain) described a method of evaluating elastic and plastic strain fields by first drawing a network of straight, irregularly spaced but identifiable fine scratches with rouge paper on a reasonably polished test surface, then taking exact, dimensionally stable replicas of these scratch systems in a fusible alloy, and finally measuring the distances between selected cross-overs on the replicas under a microscope and comparing the results from replicas taken with and without load or at various stages of assembly or service[1]. Measurement and evaluation of the replicas require some time, but are entirely independent in time and locality from the taking of the replicas, which is simple and rapid; the method allows reconstruction of whole strain fields (replica about $\frac{3}{8}$ in. in diameter) and strain histories.

The moiré fringe method can be used for a similar purpose. Dechaene (Belgium)[2] and Diruy (France)[3] described such applications, in which a photographic emulsion with the imprint of a fine grid of lines is fixed to the test surface and, when deformed under load, is photographed through a second grid on a transparent undistorted plate held in front of the testpiece, so that the moiré fringes appearing on the photograph permit evaluation of the strain field. Dechaene showed the strain concentration in a notched plate under tension at the moment of fracture, while Diruy demonstrated the use of strain rosettes based on this principle. Loof and Sande (Holland) applied the more conventional moiré fringes by bending plates to "analogous" problems, e.g., thermal stresses in discs and, by the use of rather far-reaching simplifications, stresses in shells.

The search for a robust brittle coating indicating a known elastic or plastic strain by its cracking continues in many countries. Hickson's water-soluble lacquer is simple to apply, but requires a restricted humidity range. The Union Technique de l'Automobile et du Cycle (UTAC., France) have developed a method of applying undissolved powdered resin with a flame-spray gun to metal surfaces (Fig. 1). This method is less dangerous and less subject to atmospheric influence than other known lacquers, and can be applied in the workshop and field. Small elastic strains are claimed to be detectable, and the average accuracy is 20% or, under good conditions, 10%.

The most interesting development is the use of oxide skins as brittle coatings, pioneered by Rohrbach and Feucht in Germany, in which an aluminium foil of about 0·004 in. in thickness, anodized under controlled conditions, is cemented to the test surface. The film cracks at strains of 0·5 to 3×10^{-3}, depending on test-temperature and anodizing conditions, but is unaffected by humidity, the accuracy being about 15%. The method is still in a stage of development.

In Germany, attention has long been given to methods of robust and rapid multi-point direct strain measurements on structures. One popular method, developed by Pfender, consists of staking out a gauge length at the desired measuring point by pressing two small steel balls of $\frac{1}{16}$ in. diameter partially into the test surface at a given distance and measuring the change in this distance with a precision dial-gauge which is merely held manually against the balls. For adequate sensitivity, the gauge length should be not much less than 2 in., but a new development by Feucht permits gauge lengths down to $\frac{3}{4}$ in., in which a small extensometer without a measuring device is held against the balls, and is clamped at the correct distance setting, after which it is removed and, for measuring purposes, is held against a larger instrument, suitably adapted. Elongations of 10^{-4} in. can thus be measured to within $\pm 6\%$, provided that the systematic error of the dial-gauge is known.

An interesting method of directly measuring stresses and pressures with elementary devices that need no attention and can be built into, for instance, concrete, was demonstrated by Gloetzl (Germany)[4]. Two plates, placed on top of each other, are welded together around their periphery, the stress to be measured being normally transmitted by direct contact across the plates; however, if high-pressure oil is fed into the sealed-off space, the plates will slightly separate, uncovering an outlet port in the centre (Fig. 2). The oil pressure at this stage, i.e., the maximum oil pressure observed during sustained supply of oil into the device, is a measure of the stress transmitted across the plates. A number of these devices can be operated from one hydraulic system.

Renewed interest has been shown in one of the oldest

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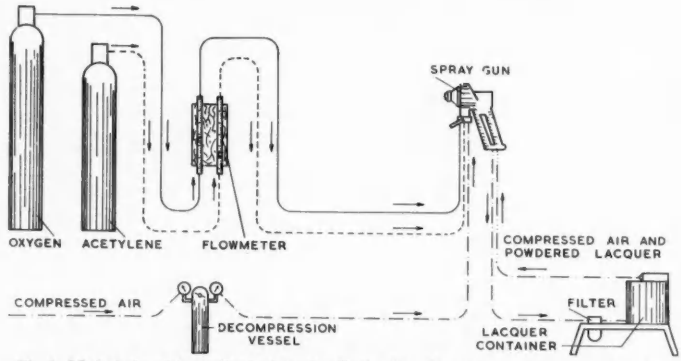

Fig. 1. **Method of applying undissolved powdered resin with a flame-spray gun to metal surfaces.**

test methods used in engineering, where full-size components or structures, or models, are tested to destruction, and the results are evaluated, statistically if need be, in terms of safe loads or of load-carrying capacity, as compared with simple testpieces amenable to calculation and standard testing. Kaufman and Smeitink (Holland) have tested in this way a wide range of Y-branches in pipes under internal pressure and have compared the pressures

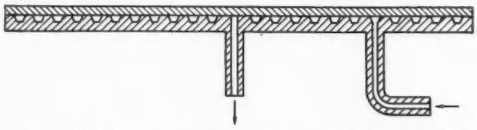

Fig. 2. **Method of measuring stresses in plates by means of high-pressure oil.**

causing yield or fracture with the corresponding pressures for straight pipes of equal diameter and wall thickness. Ligtenberg (Holland) has analysed a complicated column-beam welded connection by testing to destruction a series of full-strength testpieces and a smaller number of testpieces from which certain weld seams had been omitted, and has established a reliable picture of the elastic and plastic behaviour of this connection and of the loads transmitted at failure by the individual weld seams.

Applications

Increased experience and confidence in model testing have led to new combinations of techniques and to the use of simpler materials. French workers, for instance, have applied transparent brittle coatings to photo-elastic models, making it possible to measure cracking strains simultaneously with fringe observations. Martini (Poland) has successfully used models of lattice pylons made from folded cardboard strips glued together. Self-weight stresses have been deduced in France from tests on rubber models in air and under water. Riessauw and Lambotte (Belgium) have imitated the possible stresses and deformation measurements by strain gauges and dial-gauges wind loads, and soil subsidence by using a model (1:40) of 2-mm steel sheet loaded hydraulically at many points and placed on a circular base from which sectors could be removed. Prigorovsky (Russia)[5] has combined deformation measurements by strain gauges and dial-gauges with photo-elastic observations on composite transparent plastic models of great complexity, e.g., water-turbine runners and casings, diesel-engine frames, pistons, etc. The forces and moments in the members are here derived from deformation measurements, whilst stress distributions and concentrations are observed photo-elastically on inserted or superficially mounted optically sensitive epoxy-resin plates, sheets, or bars by conventional scattered-light or oblique-incidence methods.

In the photo-elastic section, Fessler and Roberts (Great Britain) gave a full account of a very accurate, painstaking stress-freezing investigation of a Wöhler fatigue testpiece with a transverse hole. Cylindrical shells of relatively small wall thickness have been investigated by Franz and Teepe (Germany) by a combined method of direct observation, giving the membrane state of stress, provided that the total relative retardation is small, and of a surface reflection technique giving the maximum bending stress. For the reflection technique, part of the surface of the model is painted with aluminium paint to which an Araldite foil, 0·012 in. thick, is glued. The versatile, sensitive, and mobile stress-optical equipment built by Leitz for these investigators makes possible the industrial application of these and similar methods. Acloque (France) proved that under very oblique incidence, stresses stratified in the depth of the model (e.g., bending stresses in plates) can be observed photo-elastically by direct transmission, a discovery that will certainly lead to further photo-elastic developments. The reflection technique has long been used by Photo-Stress in France for qualitative and quantitative photo-elastic observations of actual machine and structural components; very thin photo-elastic layers can be sprayed on, while thicker layers are preformed in siliconized Araldite and glued on. Moretti (France) established an interesting analogy between the edge effect in water-quenched or aged photo-elastic models and the diffusion phenomena in the cementation or nitriding of steels, so that the residual stresses due to diffusion in such steel components can be inferred from the edge fringes of similar photo-elastic models. Finally, the photo-elastic observation of impact phenomena has continued its progress towards practical significance in a report on transverse impact stresses in notched beams and in a verbal contribution on central impact on clamped discs, both from Germany.

Wire-resistance strain gauges find more and more interesting applications. Thus, Darnault (France) has measured the tension in individual wires and strands of aluminium and steel cables with special gauges. Strain gauges have been used on piles to measure stresses during pile-driving (Holland), to measure vibrations and supervise the operation of funiculars (Germany), as a complete instrumentation of wind-tunnel balances (Switzerland), and to study the behaviour of concrete-steel shaft linings in mines (Holland). Miniature gauges have also been used for the investigation of screw and rivet connections (Germany). A fundamental investigation by Rohrbach and Czaika (Germany) into the behaviour (e.g., creep) of strain gauges and its explanation by means of a mathematical " model " concept, was particularly interesting.

Further applications cited include the use of coupled pendulums for measuring the rigidity of structures and components, or models of structures, by observation of beat frequencies (France). As thin-walled welded or riveted structures are frequently used in engineering and

offer certain repeating types of stress fields, a great number of tests has been carried out by Kloth (Germany) with brittle lacquer and short gauge-length extensometers on these types of structures, and it is hoped to publish for the benefit of designers an " atlas " of stress fields typical of such constructions.

INSTRUMENTATION

Wieringa (Holland) showed a prefabricated strain-gauge bridge (Fig. 3) for use on large structures or ships, in which two active gauges are fixed to a thin metal strip, and two dummy gauges to either side of a foil fastened to the strip at one end only. The four gauges are wired as a complete Wheatstone bridge, the corner leads being taken out by insulated wires vulcanized into a rubber cap, which is cemented to the strip in order to protect the gauges and to form a permanently water- and air-tight unit that can be cemented to test structures and can be removed after testing and be used several times.

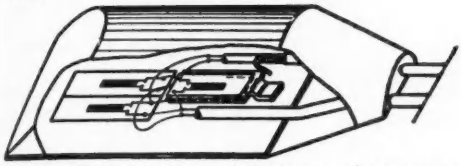

Fig. 3. **Prefabricated strain-gauge bridge for use on large structures.**

A load cell approved by the French Department of Weights and Measures as accurate to within 0·1% was also described, while Rohrbach (Germany) demonstrated a miniature load cell, comprising a strain-gauge wire coiled onto a glue-impregnated paper strip bent round a small mandrel and stabilized in this shape by wetting and drying; connecting leads are soldered on and the gauge is then glued into a small steel cylinder or incorporated into a cast pellet of Araldite *B* with studded steel plates attached at the top and bottom to provide a nearly uniform compression of the pellet. The overall diameter of the Araldite load cell is 0·16 in., and its height is 0·1 in.; its use is limited to temperatures below about 50°C and to short-time loading, in order to restrict possible errors due to the creep of Araldite.

Wire strain gauges with a glass-cloth backing, or foil gauges with a strippable backing, are being used at temperatures up to 700° or 900°C with " Brimor " cement, while a calibrator with automatic temperature control up to 660°C was also described (Great Britain).

The design of slip-rings for the transmission of strain-gauge or thermocouple signals from rotating parts is by no means final. Thus, Hoffman (Germany) described a slip-ring of 10 in. diameter, formed by $\frac{1}{8}$-in. diameter silver wire embedded in Araldite and ground and polished to a hemispherical cross-section, each ring being contacted by four silver-graphite brushes under a pressure of 1 oz at arbitrary points on the circumference. Rohrbach (Germany) demonstrated his small mercury slip-ring, which is persistently free from noise and has only the disadvantage of a limitation on the possible number of rings[6]. Kohler (Great Britain) gave details of a ring in which the mercury rotates in an internally grooved ring around a stationary disc; the centrifugal forces acting on the mercury ensure uniform contact over the whole periphery, so that high-frequency signals are transmitted without distortion at speeds as high as 5000 rpm or even higher. Another means of reducing slip-ring noise is by means of the circuit shown in Fig. 4, where R_a and R_d are active and dummy gauges, R_1 are bridge resistances, and S_1 and

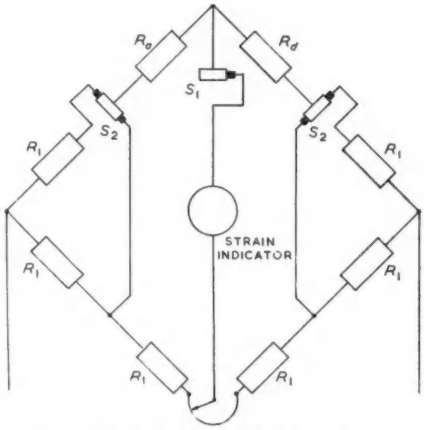

Fig. 4. **Circuit used for reducing slip-ring noise.**

S_2 are slip-rings with one and two sets of collectors respectively. The need for absolute purity of the mercury and for precautions against contamination by dirt is stressed.

Among other strain-measuring instruments, the capacitance pick-up is remarkable because of its extraordinary sensitivity and range; two possible associated circuits developed in Holland were shown, but the problem of atmospheric influences remains to be solved. A remarkable newcomer is the screening transducer of Noltingk (Great Britain), based on the principle shown in Fig. 5,

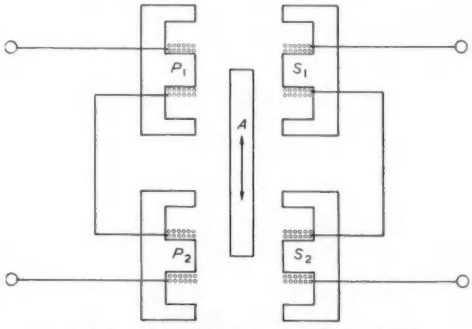

Fig. 5. **Principle of the Noltingk screening transducer.**

in which the exact position of an electrical screen *A* interposed between two primary coils P_1 and P_2 wound in series and two secondary coils S_1 and S_2 wound in opposition affects the output linearly over a large range at a rate of about 0·7 V/mm screen displacement. The output is insensitive to all screen motion except in the desired direction, the small light aluminium screen is easily attached to any moving member, unrestricted overtravel

(*Concluded on page 212*)

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A Review of Direct-Reduction Ironmaking Processes

By E. S. Paige

During the past ten years, increasing attention has been paid in most steel-producing countries to ironmaking processes offering an alternative to the blast furnace, which represents one of the largest capital outlays, not only in the iron and steel industry, but probably in the whole industrial field. It is true, of course, that the blast furnace has a great many advantages; thus, it is a continuous-flow process which permits high labour productivity, and its byproducts, such as coke-oven gas, blast-furnace gas, and slag, can to a great extent be utilized. Furthermore, the heat content of the iron can be saved by feeding hot metal into open-hearth, Bessemer, or electric furnaces, while recent developments, such as the application of self-fluxing sinter and of high-percentage sinter burden, the use of high top pressures and high blast temperatures, and the automatic control of charging, have considerably improved the performance of the blast furnace.

Despite the above advantages, there are many signs which indicate that these developments are nearing their peak and that no further increase in the capacity of blast furnaces or in the volume of ore preparation can considerably improve the efficiency or decrease the cost of pig-iron production. In addition, the need for a new approach to ironmaking has become more pressing for the following reasons:—

(1) The reduction of iron ore by carbon monoxide formed during the partial combustion of coke is a relatively slow and ineffective process, handicapped by the high percentage of flux which must be melted. Thus, although theoretically it is possible to reduce one ton of iron at the expenditure of only 8,500,000 BTU, few blast furnaces have a fuel consumption below about 15,000,000 BTU, while a further 3 to 5,000,000 BTU are required to refine the pig iron in the steel furnace.

(2) The iron and steel industry has to deal with increasing amounts of low-grade ores, requiring extensive ore preparation, such as roasting, drying, crushing, sintering, or pelletizing, thereby increasing the cost of production.

(3) The high-quality hard coke essential for the blast-furnace process is becoming more and more scarce.

(4) Owing to price fluctuations and the scarcity of scrap, a new melting stock of high iron content is needed for electric and open-hearth furnaces.

(5) Underdeveloped countries, which may have access to cheap electric power or natural gas but do not possess coke or high-quality iron ore, require a flexible process which can operate in small units and which can be easily adapted to their special conditions.

The object of the present study is to summarize the latest progress in the various techniques proposed or developed to provide an answer to the problem of producing iron without a blast furnace. Among the many different unconventional ways of making iron, exceptional importance attaches to the direct-reduction processes, which employ low reducing temperatures and a simple reducing technique based on solid or gaseous fuels, and which produce sponge iron or iron powder, instead of pig iron. The picture would not be complete, however, without including ironmaking methods which result in products similar to pig iron, but which utilize inferior fuels and new types of equipment, such as low-shaft furnaces, electric smelting furnaces, or rotary kilns.

Early History of Direct Reduction

Most direct-reduction processes have a great deal in common with ancient methods of making iron, the Krupp-Renn process, for instance, being a successor to the mediaeval German " Rennfeuern " and the charcoal/electric furnace, which has its roots deeply entrenched in the early development of ironmaking in Scandinavia. Although the monopoly of the blast furnace remained unchallenged since the early 14th century, when it was invented in Bohemia, many attempts were made during the last hundred years to bring about a renaissance of the more ancient methods of ironmaking.

The first signs of this revival can be found as far back as 1846, when Clay devised a special reverberatory furnace, in which iron ore was mixed with fine coal and reduced to metallic iron. At the end of the last century, Chenot was awarded a gold medal at the World Exhibition in Paris for the demonstration of his sponge-iron process employing a rectangular tower filled with ore and charcoal. The Renton process, devised in 1854 in the U.S.A., used a special vertical square-shaped shaft containing sixteen individual reduction columns situated on top of a hopper and connected by ducts to a melting hearth. One of its successors, the Irving process, comprised a vertical retort and a combustion chamber in which a mixture of finely ground magnetite and hematite was charged and reduced by a stream of rising carbon monoxide.

The first practical sponge-iron processes originated in Sweden before World War I, and may be said to mark a new chapter in the history of the direct reduction of iron. Since then, many new developments have taken place, including processes for reducing iron ore directly to steel. Indeed, the great variety of these developments makes classification extremely difficult. While previous authors have usually divided the field in terms of either the fuels or the equipment used, it appears to be more satisfactory to classify the different processes according to their end-products, and for this reason, the present study is divided into the following main classifications, i.e., sponge-iron processes, unconventional pig-iron processes, and direct-steel processes.

Sponge-Iron Processes

In general, the direct reduction of iron ore in sponge-iron processes is carried out with either solid or gaseous fuels, depending on local conditions.

Direct Reduction with Solid Fuels

Most processes under this heading make use of rotary kilns in which the ore is heated rapidly in an oxidizing atmosphere to eliminate sulphur pick-up, to minimize sticking, and to ensure easy temperature control of the reduction.

Originally devised in Norway for separating iron ore from ilmenite and for recovering titanium dioxide, the R-N process has been perfected in the U.S.A. by the Republic Steel Corporation and the National Lead Company at their pilot plant at Birmingham, Alabama (Fig. 1). While initial experiments were carried out with natural gas, the process is now based on the use of solid fuels, such as coke-breeze, low-grade coal, anthracite

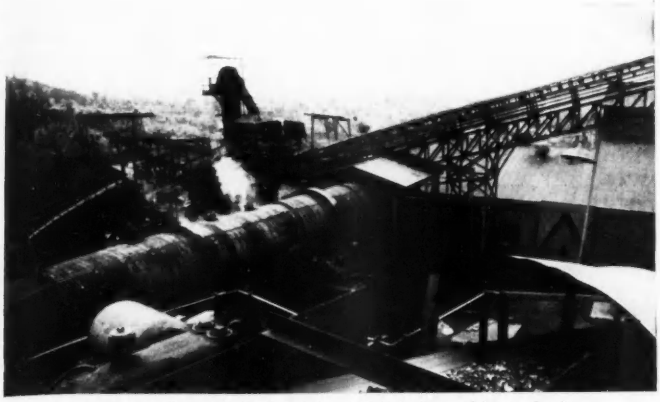

Fig. 1. General view of the R-N pilot plant at Birmingham, Alabama, showing the rotary kiln.

fines, and lignite. Low-grade and high-grade iron-ores, and magnetic and non-magnetic iron ores can be reduced by the R-N process, in which the ore and fuel are fed into a rotary kiln, together with small additions of limestone to absorb the sulphur content of the ore.

Reduction is carried out at a temperature of 1900°F, i.e., well below the melting point of iron and gangue. After a cycle of 8 to 12 hours, the products are successively withdrawn from the kiln in the form of a chemically separated lumpy conglomerate of iron powder and tailings. The lumps are then crushed, magnetically separated, and formed into briquettes. It is stated that comparatively small plants of about 200,000 tons annual capacity can operate commercially on this process and that the briquettes produced can be charged directly into the steel furnace.

A similar development, the Laramie process, sponsored by the U.S. Bureau of Mines, utilizes inferior ores in two experimental kilns, one about 50 ft long and 6 ft in diameter, the other 30 ft long and 9 ft in diameter, with a total output of 10 tons per day. In the operation of the plant, many difficulties have arisen, particularly owing to the sticking of the molten charge to the furnace walls.

Two interesting methods using solid fuels have been devised by Bo Kalling in Sweden. The Kalling-Avesta process employs an experimental rotary furnace into which coal and rich iron ore are charged, heated by special electrodes, and reduced to iron powder. This technique has not come up to expectations, and the plant has therefore ceased operation. However, high hopes are attached to a second experimental development, designated the Kalling-Domnarfvet process, which employs a rotary kiln. In this process, all heat is supplied by the charged coal to the ore, and combustion is achieved by blowing air above the charge through small nozzles. The results reported seem to be promising, once the initial difficulties experienced in connection with the relatively high sulphur pick-up and the large amount of slag to be separated from the sponge have been overcome.

For a long time, the Krupp-Renn process was not regarded as a " true " direct-reduction technique since, owing to their high impurity content, its products could not be used as a substitute for pig iron. Recent experiments have shown, however, that these products can be desulphurized in the solid state, either by a continuous or a discontinuous process, and have brought about a spectacular revival of interest in this process. Basically, a Krupp-Renn plant comprises three units, i.e., an ore-preparation plant, rotary kilns, and a dressing plant. The process deals mainly with low-grade ores, which are first washed, dryed, crushed to suitable size, and charged into the rotary kiln, together with coke-breeze, non-bituminous coal, or anthracite fines. The slightly inclined kiln rotates at a slow speed, causing a continuous descent of the charged mixture. The ores are preheated in the first two-thirds of the kiln, the reduction being completed in the remaining third in the so-called " nodulizing " zone at temperatures between 2200 and 2400°F. Most of the heat is provided by the combustion of charged fuel, but at the output side a small heating flame is used to control the temperature of the nodulizing zone, and air is introduced to provide rapid combustion of the carbon. At the end of the reduction cycle, the finely divided iron particles form compact nodules, called " Luppen ", which are separated from the highly acid slag and despatched to the dressing plant for final crushing, screening, and magnetic separation.

The Krupp-Renn process was widely employed during the last war, and at one time thirty-five kilns were in operation all over the world, representing a total annual capacity of about 1,000,000 tons. Most of these plants were located in Germany and were dismantled after the war, but one of the best-known installations (at Salzgitter-Watenstedt) was reconstructed in 1956. This plant (Fig. 2) now has three kilns, respectively 295, 315, and

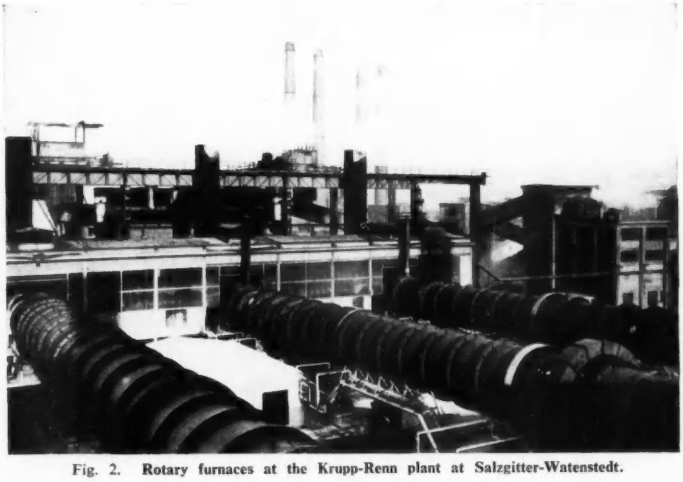

Fig. 2. Rotary furnaces at the Krupp-Renn plant at Salzgitter-Watenstedt.

360 ft in length and from 14 to 15 ft in diameter, providing a total output of about 2000 tons per day from ore containing 30 to 35% iron.

The Krupp-Renn process is also widely used in the Far East, where, for instance, one plant in South Korea reduces magnetite ores containing from 55 to 60% iron to Luppen, which are shipped to Japan and then refined to steel. Another installation at Kuji, Japan, reduces iron sands with a high content of titanium dioxide.

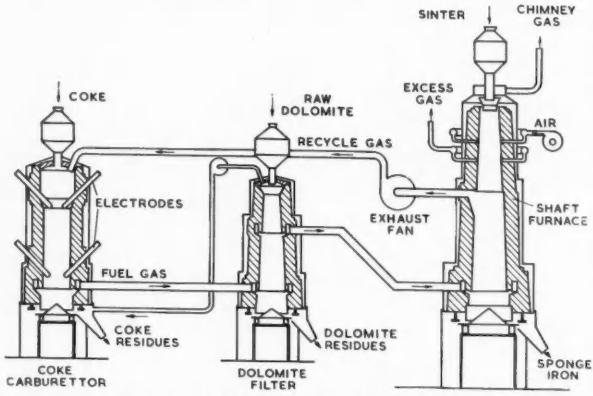

Fig. 3. Diagrammatic layout of the Wiberg plant, showing the shaft furnace, dolomite filter, and coke carburettor.

About sixteen Krupp-Renn kilns are reported to be in operation in Czechoslovakia, producing Luppen as a blast-furnace charge, the best-known of these being installed at the Kraluv Dvur works. Among other recent installations, the Krupp-Renn plant erected at Larymna, Greece, reduces iron ores containing a high percentage of nickel, while another new plant at Aviles, Spain, utilizes iron ores containing from 30 to 40% iron and from 20 to 30% silicon dioxide.

Further development of the Krupp-Renn process has been achieved with an experimental rotary kiln installed at Rheinhausen, Germany. This new development, designated the Krupp sponge process, reduces finely ground ores at atmospheric pressure and at very low temperatures to a sponge containing about 90% metallic iron, thus providing a suitable steel-furnace charge.

The only solid-fuel method which does not use rotary kilns is the Höganäs process, on which are based fully mechanized plants in operation at Höganäs and at Oxelösund, Sweden, and at Riverton, N.J., in the U.S.A. In this process, small pieces of rich iron ore, sinter pellets, or ore fines, together with a mixture of coke-breeze and limestone, are charged into saggars which are then sealed and held in a tunnel kiln for 36 hours at a temperature of about 2100°F. These plants, which have an average output of about 25,000 to 30,000 tons per annum, produce a high-quality sponge with a metallic iron content of 93%, which is utilized as a melting stock for special steels or as a raw material for use in powder metallurgy.

Direct Reduction with Gaseous Fuels

Among direct-reduction processes using gaseous fuels, the Wiberg, Norsk-Staal, Stelling, and Norwegian H-Iron processes employ shaft-type reduction furnaces and fuels obtained by gasification of coal or coke. On the other hand, such processes as the (American) H-Iron, the Esso-Little, and the U.S. Steel Nu-Iron processes are based on the fluidized-bed technique, in which, during reduction, processed natural gas or waste gases from oil refineries are used to keep the particles of finely divided iron ore in suspension and to make them behave like fluids. In this connection, the recent discovery of iron-ore deposits in a number of countries where no coking coal, but large supplies of natural gas or waste gases from refineries, can be obtained has given added importance to fluidized-bed techniques of reducing iron.

Shaft-Furnace Reduction Processes

One of the oldest and most established shaft-furnace reduction processes is the Wiberg process, in which sinter is fed into the top of a shaft furnace (Fig. 3), preheated, and reduced first to iron oxide and then to metallic iron in an ascending stream of a mixture of hydrogen and carbon monoxide. The gas is produced from coke in an electrode-heated gas carburettor and is desulphurized in a dolomite filter before entering the reduction furnace.

Heat distribution in the furnace itself is very favourable, since the maximum temperature is confined to the furnace and three-quarters of the gas is recirculated, permitting a fuel consumption of only about 9,000,000 BTU per ton of iron, i.e., the lowest consumption of all direct-reduction processes. The first plant on the Wiberg principle was erected in 1918, and at present five plants are operating in Sweden, with a total output of about 100,000 tons of iron sponge per annum. It should, however, be noted that the drawback of this process is that it requires a fair amount of ore preparation, and it is questionable whether full advantage could be taken of its remarkable fuel economy without the high-purity magnetite ores and the cheap hydro-electric power available in Sweden.

To avoid crushing and agglomeration of the ore particles in the shaft furnace, the Norsk-Staal process, pioneered in 1924 at Trondheim, Norway, and developed

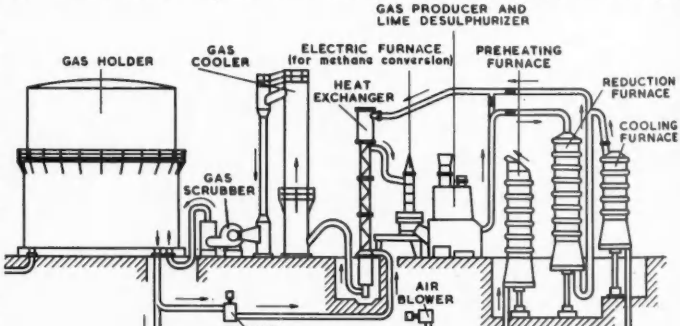

Fig. 4. Schematic layout of the Norsk-Staal plant at Bochum.

to a production stage in 1932 at Bochum, Germany, is based on the use of large squat cylindrical containers, each with a perforated fireclay bottom, made to fit one on top of the other to form a type of shaft furnace (Fig. 4). These containers are set up into three columns or shafts, arranged in such a way that, while the first shaft is being preheated and the sponge is being cooled in the third shaft, actual reduction, initiated by a preheated mixture of hydrogen and carbon monoxide, takes place in the second shaft. In operation, the containers, each holding about 3 tons of ore, are moved every 1¼ hours, a fresh container being placed at the top of the preheat column, and the bottom container transferred to the bottom of the reducing column. At the same time, the fully reduced container at the top of the reducing column is moved to the top of the cooling column, and the bottom container is taken away completed. To effect the necessary movement of the containers, hydraulic gear is used, but, owing to the complexity of this equipment and the mechanical complications introduced, this process has not proved practical and is no longer used.

A small experimental unit at the Royal Institute of Technology, of Stockholm, operates on the Stelling design, which is claimed to achieve a heat recovery equal to that of the Wiberg process. The shaft furnace is supplied with carbon monoxide from a coke carburettor, and the reduction is carried out in three phases, the ore being first preheated and further oxidized, then pre-reduced to wustite, and finally reduced to cementite.

The Norwegian H-Iron process, patented a few years ago, uses a special shaft furnace heated by ring-shaped perforated electrodes to 1650°F, where the charge of pelletized ore fines is reduced by gases containing a high percentage of hydrogen.

Owing to adequate contact between gas and ore, and uniform heat distribution, all the shaft-furnace processes described have the advantage of a favourable heat balance; they are less successful, however, in ensuring continuous flow, have a low output per unit, and, with the possible exception of the Wiberg design, give rise to many operational difficulties.

Fluidized-Bed Processes

The fluidized bed is the basic feature of several processes which differ mainly in the types of vessel in which the reaction takes place. They differ also in the method of production, the circulation and composition of the gases, the pre-treatment of ores, and the post-treatment of the finished product, which in most cases is iron powder.

Developed in America by Hydrocarbon Research, Inc., in collaboration with the Bethlehem Steel Company, at Trenton, N.J., the H-Iron process makes use of the latest petroleum refinery techniques. In this process (Fig. 5), the iron ore fines are first dried and preheated to about 900°F in a rotary kiln, transferred through an ore-bin to a charge-hopper, and pressurized with hydrogen to about 650 psig. When valves in the line between the reducer and hopper are opened, the ore fines flow under a pressure differential of about 150 psig at their settled density into the reducer vessel, where a series of fluidized beds permits a good countercurrent contact of ore and hydrogen during the 6-hour reduction cycle. The iron powder is removed from the reducer to a dump-hopper and is then transferred to an agglomerating mill, where H-Iron briquettes are formed for steel-furnace charge.

The hydrogen used in this process is produced by partial oxidation of natural gas with oxygen, while the wet hydrogen leaving the reducer is cooled in three stages, i.e., (1) in a heat exchanger against recirculated dry hydrogen, (2) by direct contact with cooling water, and (3) by freon refrigeration, after which carbon monoxide and carbon dioxide are eliminated by reforming and scrubbing, and the hydrogen is then recirculated.

The H-Iron process appears to be fundamentally sound, but depends largely on the supply of cheap natural gas and fine ore concentrates. Its product has been successfully used as a melting stock in electric furnaces but has the inherent disadvantage of a cold charge.

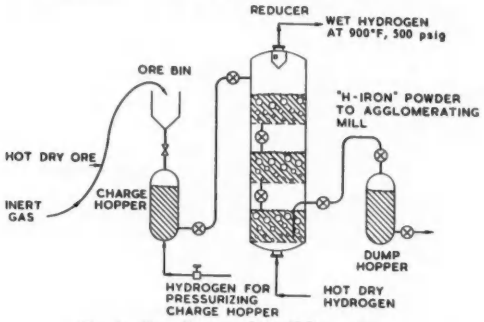

Fig. 5. **Flow diagram of the H-Iron process.**

The Esso-Little process is designed on principles similar to those of the H-Iron process, with the main difference that the gases are not recirculated. The reducing gas used is a mixture of air and natural gas of high calorific value, making it possible to maintain a temperature of about 1500 to 1600°F in the fluidized bed. Although the elimination of recycling of the gases may simplify the plant, it is questionable whether the saving in equipment will not be offset by the less favourable heat balance of the process.

Another fluidized-bed technique, the U.S. Steel Nu-Iron process, makes use of a two-stage reduction chamber. The bottom reduction chamber receives a preheated mixture of carbon monoxide and hydrogen, which reacts with the preheated ore fines to remove oxygen and to maintain a temperature of about 1300°F. After the first stage, the ore and gases are transferred to the top reduction chamber to initiate reduction, removing the remainder of the oxygen from the ore. The product of this process, owing to its large percentage of iron oxide, is a suitable raw material for making low-carbon steel.

Of other fluidized-bed processes, reference should be made to the Novalfer-Onia process, under development by the Office National Industriel de l'Azote at Toulouse, France, and specially intended for the reduction of Algerian ores by a mixture of carbon monoxide and hydrogen at a temperature between 1100 and 1300°F. At present, tests are being carried out with a number of small reducing vessels of from about 8 to 16 in. in diameter, and a 10-ton pilot plant is under construction.

Finally, mention must be made of a few developments which do not, strictly speaking, employ fluidized-bed techniques, but which have certain points of similarity. An example is the rotary furnace used in the Scortecci process at the Dalmine pilot plant of the Instituto Siderurgico Finsider, of Genoa, where various grades of Italian ores are treated with hot cracked natural gas containing 85% hydrogen. The sponge iron produced has been found to be a suitable electric-furnace charge, even without the addition of scrap.

A new series of tests has been carried out in the U.S.A.

during the last few years at the Longview plant of the Madaras International Corporation. The installation, which was tried out on a semi-commercial scale during the last war, comprises a stationary vessel into which hot gas is introduced intermittently at 20 pulsations per minute at a pressure of about 40 psig, to reduce the charged ore pellets to sponge iron in a 3- to 5-hr preheating cycle and a 2- to 2½-hr reduction cycle. During these tests, many technical difficulties have been encountered, and the use of pulsating pressures has not as yet fulfilled expectations.

Sinter pellets of rich ore concentrates are preheated in an electric induction shaft furnace and reduced by natural gas to sponge in the Galluser process, sponsored by Lurgi GmbH, of Frankfurt, and Charmilles, of Geneva. In this process, cold gas, comprising a mixture of carbon monoxide and hydrogen, is admitted at the bottom of the induction furnace, and during its ascent is heated while cooling the reduced pellets, preventing their re-oxidation. At the same time, natural gas is admitted to the reduction zone of the furnace, where it is cracked to form hydrogen, carbon monoxide, carbon dioxide, water, and from 0·5 to 3% carbon, the formation of this latter product being inevitable. The exhaust gases are then freed by condensation and scrubbing from steam and carbon dioxide, and are recirculated at the bottom of the furnace. This process is not yet ready to be used on a production basis, and the published figures of fuel consumption (850 to 1000 kWh of electric current and about 7000 cu ft of methane or 350 lb of coal per ton of metal) can only be regarded as preliminary experimental data.

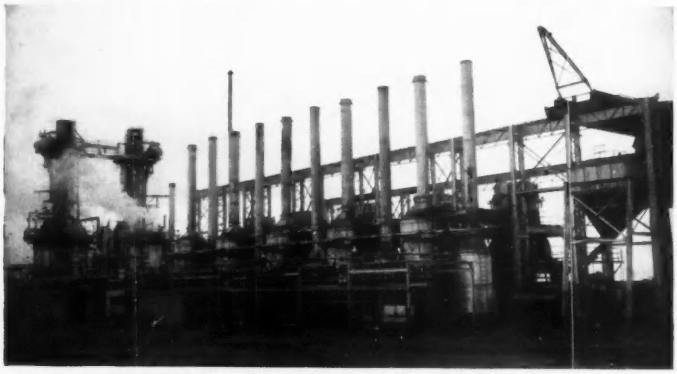

Fig. 6. View of the 200-ton HyL plant at Fierro Esponja, showing the two gas reformers and the five reducing reactors.

Originally developed by Hojalata y Lámina S.A. at their pilot plant at Monterrey, Mexico, the HyL process has been perfected and has now reached the production stage at the Fierro Esponja plant with the co-operation of the M. W. Kellog Company, of New York. Five reactors operate at the Fierro Esponja plant (Fig. 6), in conjunction with a separate gas-reformer plant. Ore, in sizes ranging from ¼ to 1½ in., is charged without any preparation into the reducing reactors, each of which can hold about 30,000 lb. The natural gas is first reformed by steam in two gas-reformer furnaces, and is then scrubbed, preheated, and blown at a pressure of 50 psi through the vessel to bring about a reduction of the charged ores. The group of five vessels is so arranged that, while one vessel is charged, the other four are in different stages of reduction. When the gas becomes saturated with steam, it is withdrawn, quenched, reheated, and re-admitted for a second reduction cycle. The reactors are dumped every four hours, and the sponge, which has an average of 86% metallic iron or 90% total iron content, is charged into the adjoining electric furnaces with a varying percentage of scrap additions. The availability of cheap labour, the rich ore deposits, and the favourable conditions of the site permit great savings in capital and production costs at this plant, which has a capacity of 200 tons per day. It is now reported that erection of a second 500-ton full-scale production plant has been approved, and construction will shortly be started at Fierro Esponja.

A pilot plant utilizing natural gas and producing a sponge iron containing 90% iron is operated by the Oil Institute of the Soviet Academy of Sciences in Russia. The fuel consumption of the process is comparatively low, ranging from 6·5 to 8 cu ft of natural gas per pound of iron reduced. A fluidized-bed magnetic-roasting process has also been successfully tested on a pilot-plant scale, and construction of a large-scale experimental plant was reported some time ago. A combined solid- and gaseous-fuel process, under investigation for use in regions without dequatae natural-gas resources, envisages heating of the fluidized bed of lean ores by pulverized solid fuel and the final reduction of the ores by natural gas.

Unconventional Pig-Iron Processes

The processes described under this heading differ from "true" direct-reduction processes in that their end-product, as distinct from sponge iron, has much the same properties as the product of the blast furnace. The equipment used in unconventional pig-iron processes may be classified into low-shaft furnaces, rotary furnaces, and electric smelting furnaces.

Low-Shaft Furnaces

Basically, the low-shaft furnace is nothing more than a small blast furnace which does not have to deal with the crushing effect of the burden and can therefore operate satisfactorily with lower-grade fuels. Another great advantage of the low-shaft furnace is that it does not require much ore preparation and can be built in small units at comparatively low capital cost. Considerable development has taken place in this direction in Italy and in Eastern Germany, where inferior ores have been successfully reduced to pig iron with low-grade fuels, including briquettes made of lignite.

A briquetted charge is used in the Humboldt process, developed by Demag at Cologne. In this process, ore, coal, and flux are finely ground, mixed with a binder, and compressed into briquettes, which are then charged into a low-shaft furnace and reduced in an oxygen-enriched blast to pig iron. This principle is expanded in the Weber process, in which the briquettes are first carbonized in a retort before charging them into the low-shaft furnace.

Some years ago, O.E.E.C. initiated construction of an experimental low-shaft furnace at Ougré, in Belgium, where tests were carried out in accordance with a joint research programme of the participating nations. Opinions have differed, however, as to the value of these experiments, and at present the plant, called Furneau

Experimental International, is rather used as an experimental blast furnace than a low-shaft furnace.

Rotary Furnaces

Most of the furnaces under this heading have primarily been developed for the production of slag for cement or similar materials, pig iron being regarded in this connection as a byproduct. Thus, the Basset process, in commercial use at Aalborg, Denmark, employs rotary furnaces, 115 to 165 ft in length, to reduce burnt pyrites by the combustion of coke-breeze and oil at a temperature of about 2350°F. Fuel consumption is about 1450 lb of coke-breeze and 775 lb of oil per ton of iron.

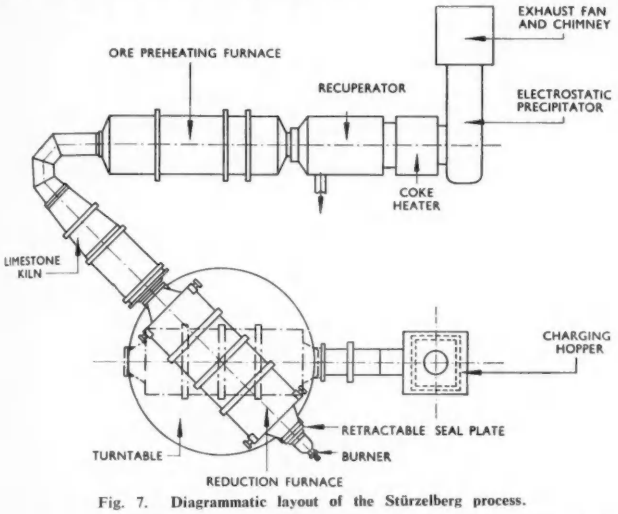

Fig. 7. Diagrammatic layout of the Stürzelberg process.

A very short rotary kiln is used in various developments based on the Stürzelberg process (Fig. 7), the kiln being mounted on a turntable to permit firing from both sides and having an end-tipping motion to facilitate the discharge of the rather pasty slag. The estimated fuel consumption is about 1550 to 2200 lb of coke-breeze or about 1325 to 1500 lb of pulverized coal per ton of iron. Although this process is rather costly, owing to the hard wear on refractories and the absence of continuous charging and handling equipment, it is in some cases a practicable proposition for reducing ores containing a large percentage of zinc oxide or other volatilizing impurities which cannot be treated in the blast furnace.

The French Azincourt process employs a rotary kiln, about 95 ft in length, with a specially shaped combustion chamber, where preheated iron ores of 38 to 55% iron content are reduced in a countercurrent of natural gas, coke-oven gas, or gases of other fuels at a temperature of 2550 to 2750°F. This process produces slag for cement and pig iron with an average content of 1 to 3% carbon, 0 to 3% silicon, 0 to 0·7% manganese, and 0·15 to 0·7% sulphur. This pig iron has the advantage that, after some treatment, it can be used as a liquid-steel furnace charge.

Electric Smelting Furnaces

The basic principle of electric smelting is that it partly replaces solid or gaseous fuels by an electric current and the fuels are required solely as a reducing agent. The first production plant of this type was the combined charcoal/electric smelting furnace inaugurated in 1910 at Jernkontoret, Sweden. This furnace is similar in construction to the conventional blast furnace, differing only in its lower part, which has a wide melting chamber. Several furnaces of this type were built between 1914 and 1930, mostly in units of 50 tons daily capacity, with a fuel consumption of about 700 lb of charcoal and about 2000 kWh of electric power per ton of iron produced. In 1952, two of these units were still operating in Sweden.

A more up-to-date version of electric smelting is achieved with the Tysland-Hole electric furnace, which is in many ways analogous with a conventional electric-arc furnace but utilizes, in addition to electrodes, coke-breeze or other low-grade fuels. Several furnaces operate on this principle in Norway, Sweden, and Italy, the largest with an annual capacity of 80,000 tons. Although their coke-breeze or other solid-fuel consumption is low, they consume large quantities of electric power.

The Norwegian Edwin-Elektrokemisk process combines a rotary kiln with an electric smelting furnace to produce good-quality pig iron. The kiln is heated by oil burners to a temperature of about 1900°F to pre-reduce the ore, while reduction is completed in the adjoining electric furnace. It is interesting to note that, although the exhaust gases of the electric furnace are used to preheat the kiln, the heat balance of this process is not extremely favourable.

Another imaginative combination of direct reduction and electric smelting is achieved in the Strategic-Udy process, sponsored by the Koppers Co. Inc., of Pittsburgh, U.S.A. The prototype plant at Niagara Falls, Ontario, comprises a rotary kiln, 80 ft in length and 6 ft in diameter, with ore-drying, storage, and charging equipment, and three 1000-kVA three-phase electric smelting furnaces. The pre-reduced ore is directly charged into the electric furnace, using a special " floating-charge " technique, by means of which the hot pre-reduced ore slides down the sides of the furnace. This process can effectively deal with ores contaminated with titanium, manganese, chromium, and other impurities which cannot be fed directly into the blast furnace. A group of Canadian companies has recently signed an agreement for the installation of a steel plant on the lines of the Strategic-Udy process, which has yielded in trial smeltings products ranging from pig iron containing 3·5% carbon to semi-steel with 0·2% carbon.

In the MacDowell-Batelle or DLM process, a bed of iron ore and coal is reduced, while passing along a travelling chain grate, the hot liquid iron being charged into an adjacent electric furnace for final reduction.

On the whole, it may be accepted that reduction by electric smelting is a ready substitute for the blast furnace in areas where cheap electric power is available and where the quality of ores is sufficiently good or can be improved by some sort of agglomeration.

Direct-Steel Processes

A number of processes have been specifically developed in an attempt to produce steel directly from iron ore and thus to eliminate not only the blast furnace and related installations, but the steel furnace as well. One

example, the Cavanagh or O.R.F. (Ontario Research Foundation) direct-steel process, uses a longitudinal strip furnace, in which a bed of fine magnetite superconcentrate is placed on a travelling grate and heated to about 1800°F. The hot magnetite is then burned to hematite, raising the temperature very rapidly to 2200°F. The ore bed has a very high permeability and is lightly fused together, so that very high rates of gas supply can be achieved without excessive dusting or blowing of the ore. The reducing gas, containing carbon monoxide and hydrogen in the proportion of 3 to 1, is forced at a temperature of 2000°F to pass through the grate and the ore bed, permitting complete reduction of the ore within one hour. The bed of reduced iron forms a hot metallic cake and can be stripped from the travelling grate at 2000°F, which is a satisfactory rolling temperature, to permit hot-rolling of the low-density slab in a single pass to a steel sheet of about one tenth of its original thickness.

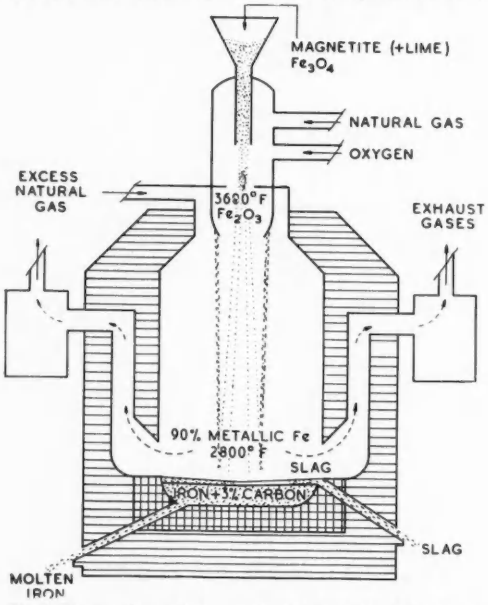

Fig. 8. Diagram of the reducing vessel used in the Jet-Smelting process.

The Jet-Smelting process of the Ontario Research Foundation reduces fine ore concentrates at very high temperatures. In the reducing vessel (Fig. 8), the charged mixture of magnetite and lime is entrained in a high-temperature flame of oxygen and natural gas, combustion of the magnetite raising the temperature of the ore particles rapidly to about 3600°F. Owing to this rapid heating, the individual particles decrepitate, creating a large amount of new surface. The natural gas then cracks in contact with the hematite, to form carbon monoxide and hydrogen, and the resulting flame with entrained dust is fired vertically downwards into a bath of molten metal and slag at a high velocity to keep dust losses low. At the final stage, complete reduction takes place under the slag cover of the molten bath. After slag removal, the molten steel or semi-steel is discharged. Since this operation avoids the impingement of iron oxide on the walls, long refractory life can be expected. The fuel consumption is, however, high, and the problem of recirculating the rich exhaust gases is not yet solved.

The only British development, the Flame-Smelting process, in an experimental stage at the Middlesborough Research Laboratories of B.I.S.R.A., differs basically from the Jet-Smelting process in that it utilizes the exhaust gases for pre-reduction of the ore, improving the heat balance and making it possible to use lower-grade ores than the Canadian process. The Flame-Smelting process, formerly known as the Cyclosteel process, uses a high-temperature reduction chamber, into the top of which pre-reduced powdered iron ore, pulverized coal, and oxygen are injected, somewhat on the lines of the Jet-Smelting process. The reduced molten iron and slag collect in a hearth at the bottom of the reaction chamber, and the hot reducing gases pass to a preheater reactor to pre-reduce the following batch of ore. No details of the reduction achieved and the quality of the steel produced have as yet been disclosed in connection with this process.

All these three direct-steel processes are pioneering methods which, if they could be applied economically to reducing low or medium-grade ores to steel, would revolutionize the iron and steel industry. However, it should be appreciated that it will take a very long time before a production plant will be able to dispense with its steel furnace.

Conclusions

(1) Most direct reduction and unconventional pig-iron processes have outgrown their development stage and may be regarded as feasible substitutes for the blast furnace in cases where high-grade ore concentrates, cheap electric power, and natural gas are available. They are also valuable in areas where low-grade ore deposits exist in conjunction with inferior fuels or natural gases and where there is a shortage of coking coal.

(2) Electric smelting furnaces, low-shaft furnaces, or direct-reduction processes using solid fuels provide a unique opportunity for medium-size works, such as iron and steel foundries, and for alloy-steel plant to install their own ironmaking plant.

(3) The economics of the processes described require further consideration, since most of the estimated investment and production costs are either of a speculative nature or are extrapolated from data of small pilot plants.

(4) In order to take full advantage of new developments, further investigations are required into optimum ore-preparation methods, the most economical reduction temperatures and pressures, and the effects of using sponge iron as a melting stock in the steel furnace.

(5) Despite the inherent advantages of the various processes outlined in this article, the superiority of the blast furnace in integrated iron and steel works is likely to remain unchallenged in the immediate future.

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Principles and Applications of "Spieth" Locking Sleeves

By H. SCHMITZ. (From *Industrie-Anzeiger*, Vol. 81, No. 20, March 10, 1959, pp. 29–32, 15 illustrations)

In addition to illustrating some of the deformation and stress problems involved when using "Spieth" locking sleeves, this article shows how their characteristic properties can lead to new design possibilities and gives examples of some typical applications.

THE search for a detachable, positively locking connection between shaft and hub has led to the development of a locking-sleeve element, patented by Spieth*, the basic design of which is shown in Fig. 1. The sleeve is of "corrugated" construction, with radial grooves alternating from the outside to the inside and from the inside to the outside. The sleeve is slipped onto the shaft with the internal locking face *a* bored to a specific dimension which includes an inner diametral clearance Δr_i. The outer diametral clearance Δr_o permits face *b* to be inserted into the cylindrical bore of the hub. Subsequently, the sleeve is clamped by an external load applied axially, resulting in the deformation shown in the lower part of Fig. 1, and causing a peripheral expansion of the outer face of the sleeve and, at the same time, a symmetrical contraction of the bore over its length. Thus, inside and outside play is eliminated, and the shaft, the locking sleeve, and the hub are concentrically locked at the points of contact *f* by a force fit. The locking faces and webs of the sleeve are stressed to assume the shape corresponding to the locked position but, on relieving the axial clamping force, the locked parts disengage again, as the deformation of the sleeve is within the elastic limit of the material.

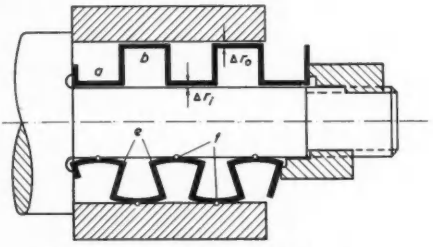

Fig. 1. **Basic design of a Spieth sleeve.**

Owing to the locking stresses occurring at the points *e* in Fig. 1, the locking faces, as well as the webs, are subjected to constant stresses. Fig. 2 is a schematic representation of an individual locking face.

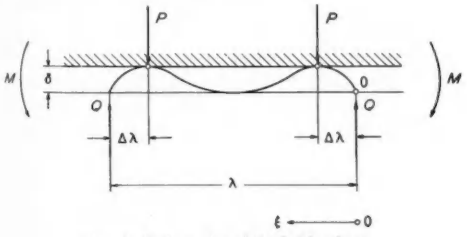

Fig. 2. **Deformation of the locking faces.**

The thin straight line represents the non-deformed generatrix of an axial section through a cylinder of non-diemnsional length λ, which is related to the absolute length by the equation $\lambda = \omega l$, in which the factor ω is a measure of the dimensions of the cross-section of the locking face. Assuming that this generatrix is subject to edge loads at the points *e* in Fig. 1, i.e., at $\xi = 0$ and $\xi = \lambda$, expressed by a bending moment *M* and a transverse force *Q* in Fig. 2, then the line of deformation usually assumes the shape drawn with a thick line in Fig. 2 and therefore attains a maximum deformation at a distance Δλ from the edge $\xi = 0$, and also, for reasons of symmetry, from the edge $\xi = \lambda$.

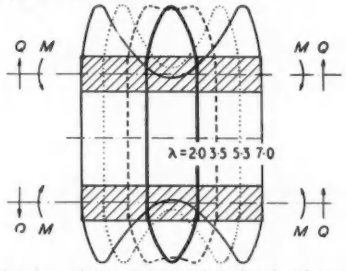

Fig. 3. **The shape of deformations with various length parameters λ.**

As illustrated in Fig. 3, at small values of the length parameter λ both maxima will fuse in the centre of the locking face to one single maximum. However, with a relatively large value of λ, the line of deformation has a wavy shape, with deflections fading out symmetrically from both maxima towards the centre. As the width of the gap δ is constant if no load is applied, the locking face will exert pressure against the mating face at the two maxima. By suitable dimensioning of the locking faces, it is therefore possible to influence at will the points of application of these forces.

It may, at first sight, appear strange that, with small values of the length parameter λ, there should be only one point of contact, whereas there are two such points with higher values of λ, as shown in Fig. 3. In this connection, it should be mentioned that this fact cannot only be demonstrated mathematically, but has also been confirmed experimentally.

STRESSES ON THE LOCKING FACES

A thorough analysis of the load in the locking face shows that maximum stress always occurs at the transition points *e* in Fig. 1 and is solely determined by the induced radial bending moment *M*. The shear stresses caused by the transverse forces and the stresses due to the Hertzian contact pressure created by the perpendicular forces need not be taken into consideration when calculating stress.

In Fig. 4 stress is plotted against a value representing contact pressure *P*. The length λ of the locking face and the frictional torque *T* appear as parameters. It will be realized that, owing to the small difference between the upper and lower limit curves in the right half of the diagram, the torque to be transmitted by the sleeve has a great effect on stress. The lowest stress in the locking face occurs primarily within the range of the left half of the diagram, the optimum value of λ being 2. The values shown on the ordinate at $P = 0$ correspond to the stress required merely to take up play.

* German Patent No. 828627

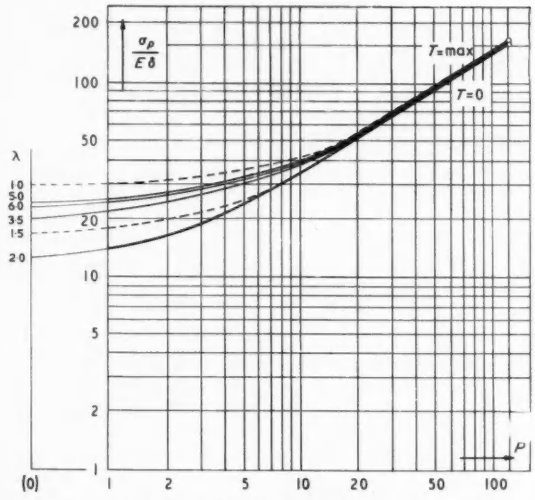

Fig. 4. **Stress as a function of contact pressure for various values of λ.**

Fig. 4 also shows that the contact pressure indicated on the abscissa depends on the ratio of the permissible stress σ_p to the modulus of elasticity E. Consequently, the material used should not be selected merely on a basis of its strength.

Optimum Dimensioning of the Spieth Sleeve

The contact forces acting between the locking faces and the mating faces give rise to frictional forces which reduce the axial load from one locking face to the other in the direction of the clamping force by the amount of the existing frictional force. Thus, the locking faces closer to the external point of pressure are subjected to a higher stress than the more remote points, with unfavourable utilization of the clamping effect, because deformation of the individual webs or locking faces remains constant over the entire length of the sleeve from locking face to locking face and hence reduces the contact forces. However, by suitable dimensioning of individual elements, Spieth sleeves can be used to full advantage. The contact forces on all locking faces are maintained constant, despite the reduction in axial load, by making those locking faces which are subjected to a lower axial load softer than the others, thereby increasing their relative deformation capacities.

Fig. 5 illustrates the advantages derived from the

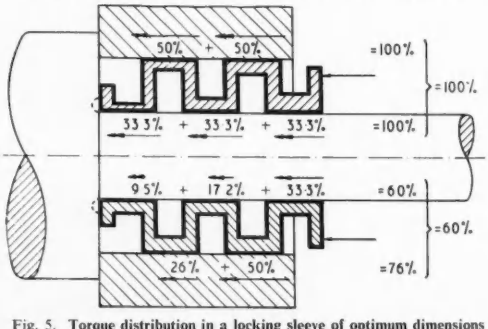

Fig. 5. **Torque distribution in a locking sleeve of optimum dimensions (*top*) and of equally dimensioned elements (*bottom*).**

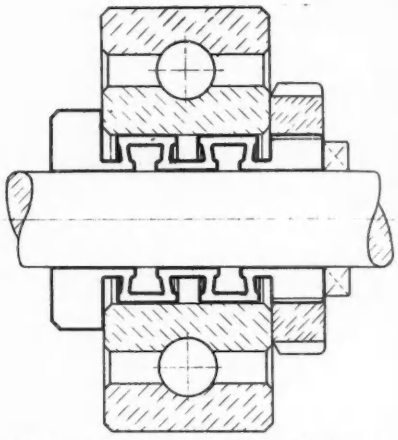

Fig. 6. **Tension sleeve for locking rolling bearings.**

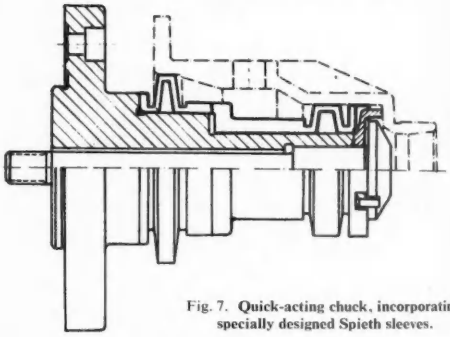

Fig. 7. **Quick-acting chuck, incorporating specially designed Spieth sleeves.**

reduction in load due to frictional forces in the dimensioning of the individual sleeve elements. The assembly must transmit a certain torque by friction. If, as shown in the top half of the illustration, the torque transmitted with optimum sleeve dimensions is taken as 100%, each locking face on the shaft and in the bore of the hub caters for the same proportion of the entire moment to be transmitted. The lower half of the illustration shows how, with equal dimensions of the individual elements over the entire length of the sleeve, the transmissible portion of the torque decreases from locking face to locking face, with a utilization of the locking sleeve of only about 60%.

Applications of Spieth Sleeves

The characteristic feature of their radially symmetric deformation opens up a wide field of application for these sleeves, especially as they are very easy to manufacture.

Fig. 6 illustrates a Spieth sleeve used for clamping a roller bearing onto a smooth shaft. In this case, contrary to the basic design described above, the locking element is designed as a tension sleeve. In another example (Fig. 7), Spieth sleeves are used in the design of quick-acting chucks, permitting the rapid setting up of workpieces within close dimensional tolerances. Other typical applications include the clamping of sleeves and the truly concentric attachment of milling cutters to spindles, while specially shaped Spieth sleeves may form the outer races of needle bearings, providing easy adjustment of radial play.

Cemented Borides as Tool Materials

By R. C. Brewer*

In a previous paper, the author has given an account of the use of aluminium oxides as cutting tools[1], and the object of the present paper is to examine, in a similar manner, the development of cemented borides for cutting-tool purposes. Some years ago, consideration appears to have been given to a boron-carbon compound in Germany[2], but its application was limited to gauges and abrasive sticks, where its hardness was a valuable asset and its lack of tensile strength relatively unimportant. More recently, serious attention has been paid to the use of various borides in chip-producing processes, at present mainly for turning operations. Some work in this connection has been carried out by a number of commercial firms in the U.S.A., but one systematic study has been effected by the Armour Research Foundation of the Illinois Institute of Technology, under the sponsorship of the American Society of Tool Engineers.

Carbides nowadays contain both tungsten and cobalt, over the supply and price of which many countries have little control; moreover, in a national emergency, the use of cobalt for cutting tools is likely to be considered of secondary importance, compared with its use for heat-resistant alloys. There are several ways in which the problem of tungsten- and cobalt-free tool materials can be approached, one of which, tried out during World War II, involved the use of nickel as the cementing medium for a solid solution of titanium and vanadium carbides; more recently, a ceramic material has been used as the binder for titanium carbide, such a tool sometimes being termed, rather erroneously, a cermet. Ceramic and oxide tools themselves meet the requirement of being tungsten- and cobalt-free, but their application is rather more limited than most of the conventional tool materials. It is an integral part of the thought behind the development of the boride programme of research that these materials should give a performance comparable with that of conventional carbides at the same or less cost. The borides have the *a priori* advantages of high hardness, high melting point, and relatively cheap preparation.

The chief borides of interest as potential tool materials are chromium, hafnium, molybdenum, niobium, tantalum, titanium, tungsten, vanadium, and zirconium. Many of these elements were previously studied by Kiessling[3,4,5,6], and all are metallic, with a high melting point, but are brittle in themselves and, like the tungsten carbide-cobalt materials, require a binder for any applications where mechanical strength is necessary. Several of these borides are resistant to oxidation to quite a high degree.

Of the elements mentioned, hafnium, niobium, and tantalum are obviously too expensive to be considered, and the replacement of tungsten carbide by tungsten boride is of doubtful advantage. Of the remainder, particular attention has been given to the borides of chromium, molybdenum, and titanium. One other boride has also attracted attention, i.e., aluminium dodecaboride (AlB_{12}). The densitity and hardness of some of these borides are shown in Table I.

Apart from the properties which are desirable in all tool materials, a boride should also lend itself to ball-milling to a very fine particle size, without causing serious corrosion troubles, and should be capable of being wetted by the bond. Bearing in mind the work of Trent,[7] it would appear desirable that the tool material should not form an alloy with any material which it is desired to cut; in the main, this means that it should not form an alloy with iron. For chromium, titanium, and zirconium borides, the temperature of the melt with iron is less than 1225°C, but aluminium boride does not form a melt until 1500°C.

Table I: Density and Hardness of Various Borides

	TiB_2	ZrB_2	CrB	AlB_{12}
Density [gm/cm³]	4·4	6·2	5·6	2·6
Hardness [VPN]	4200	3600	3300	3800

As mentioned previously, the boride particles require bonding, and metals are usually used for this purpose. The most common metallic binder in conventional tool materials is cobalt, which, for the tungsten carbide range of tool materials, is superior to any other metal. For several years, the reason for this was not well understood, but recently Rautala and Norton[8] have shown that one reason is that tungsten carbide and cobalt form a quasi-binary system at all composition ratios, no three-phase region occurring. Investigations by the American Electro Metal Corporation indicate that molybdenum borides and nickel certainly form ternary compounds and that the situation can in no way be considered as quasi-binary, but that it is possible to use nickel with molybdenum boride and to obtain a binder material which gives the required strength and ductility.

In general, a binder should form a definite liquid phase at the sintering temperature and should wet the boride effectively; the amount of liquid phase is somewhat critical, inasmuch as too little prevents densification, while too much does not permit the shape to be retained. Some of the boride particles should dissolve in the binder at the elevated temperatures of sintering, but must be re-precipitated after solidification. Above all, the formation of new phases during cooling should be avoided, since this might affect the equilibrium and considerably reduce reproducibility.

With boride materials, there are several possibilities of producing a binder, this being normally a metal whose melting point is less than that of the hard metal phase and liquid at the sintering temperature. Such a liquid phase may be produced by a eutectic between a boride and the auxiliary metal, by a eutectic between two borides of different metals, or, in view of the fact that metal-boron systems are frequently characterized by several different compounds, a eutectic between two borides of the same metal; for instance, with Mo_2B and Mo_2NiB_2, a eutectic reaction forms a liquid phase below the melting point of either boride[9], thus providing a satisfactory binder. Consequently, although nickel is required, it does not remain as nickel, but reacts to form the ternary compound Mo_2NiB_2, whereas copper acts as a normal binder, since it forms no ternary boride with any of the borides of interest as tool materials; indeed, it appears that copper does not form even a simple copper boride.

It seems safe to assume that any of the following types of bonding is satisfactory for cutting-tool purposes.

(a) *Ductile bonding*, in which the hard particles should have moderate solubility at the sintering temperature and

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low solubility in the bond after cooling[10]; the tungsten carbide-cobalt system is typical of this type of bonding.

(b) *Eutectic bonding*, which is, in some ways, similar to ductile bonding, though Glaser[11] has pointed out that any two phases which react to form a melt may be used and that the diffusion is helped if sintering is effected at a temperature a little higher than the eutectic temperature; in the U.S.A., the Borolite Corporation have used these techniques to bond zirconium and chromium borides.

(c) *Intermediate compound bonding*, in which the bond is an intermediate compound of the type usually avoided in ductile bonding and is exemplified in the conventional field of metallic tool materials by the addition to the normal cobalt of the double carbide Co_4W_2C to bond tungsten carbide for hot-extrusion dies; in the realm of borides, the case of the ternary molybdenum-nickel boride mentioned previously is an instance of intermediate compound bonding.

The bond metals which have received attention are copper, iron, nickel, cobalt, silver, and aluminium. In view of what has already been said, it might be wondered why cobalt has been chosen; the reason is that only small quantities were required, and it was thought that cobalt might modify the behaviour of the other bond metals.

A gradient furnace, covering the range between 900 and 1650°C, is a convenient way of studying the effects of temperature, the samples being placed along a refractory boat at several points whose temperatures have been determined by an initial calibration. Results have shown that all the above-mentioned metals wet the borides well but, as expected, the amount of reaction varies quite considerably. Iron was found to have the greatest solvent action on all borides, except chromium boride; nickel and cobalt have the next greatest solvent action, silver and copper exhibiting the least action in general, although copper dissolves more aluminium dodecaboride then either nickel or cobalt.

As a result of preliminary investigations [9,12], it was found that the most promising borides were those of titanium, aluminium, molybdenum, and chromium. Titanium boride with nickel as a binder showed a desirable structure, although the bond phase was complex; when copper was used as a binder, it penetrated very satisfactorily the cracks in the large boride grain and suggested that further study would be profitable, particularly since the bond hardness was very low. The high temperature at which a liquid phase forms between iron and aluminium dodecaboride has already been mentioned, and this, together with the low bond hardness, indicated that further work should be undertaken.

After eliminating the borides of expensive elements (hafnium, tantalum, and niobium) and the borides of zirconium and titanium (which had been studied already), the American Electro Metal Corporation were left with the borides of chromium, molybdenum, and vanadium. The decision not to study vanadium boride has been admitted to be rather arbitrary[9], but both molybdenum and chromium borides were known to possess certain definite advantages (discussed later) over vanadium borides.

Several aspects of the preparations and properties of boride tool materials will now be discussed in the light of the four borides enumerated previously:—

(a) *Ball-Milling*:—

Although the materials are usually in powder form, ball-milling is required in order to reduce the particle size to a point where sufficient density can be obtained, of the order of 2 microns.

For the titanium boride system, a 20%Ni-80%TiB_2 mixture was ball-milled in benzene, and examination of the sintered structures after various milling times indicated that porosity was the property most affected by milling time. With the 10% Fe-90% AlB_{12} mixture, however, there was no improvement in the density of cold-compacted samples with an increase in milling time. For the molybdenum and chromium borides, dry milling for a minimum of 40 hr appeared to be best. It was found possible to reduce this time if the milling was carried out in water, but this process was not entirely satisfactory, since oxide films tended to form on the particles, producing irregularities in sintering. Other media such as acetone, xylene, and carbon tetrachloride were tried, but dry-milling appeared to give the best results.

(b) *Compacting Pressure*:—

Titanium boride samples were compacted over a range of pressures from 3 to 33 tsi, using wax or stearic acid as a lubricant. Examination did not show any significant difference in porosity or structure which could be attributed to changes in compacting pressure.

The pressure range used for cold-compacting aluminium boride samples was much higher (5 to 80 tsi) and, indeed, it was found difficult to compact samples with 10% iron at pressures below 30 tsi. Compounds of iron and aluminium boride were also hot-pressed in induction-heated graphite dies, the pressure ranging from 2 to 7 tsi. In this case, the pressure appeared to have practically no effect on density, although the structure appeared to be affected by the rate at which the die was heated and by the amount of liquid phase present during sintering.

It has been found that the molybdenum borides are stable in contact with carbon[13], so that graphite punches and dies may be used for hot-pressing, although it is better to employ steel dies for cold-pressing, with camphor as a lubricant. Pressures of the order of 5 tsi are required. One factor which leads to bad reproducibility is uncontrolled clearance between punch and die, since this permits a leakage of material which varies with time; in general, cold-pressing gives better reproducibility than hot-pressing.

(c) *Sintering Atmosphere*:—

In all cases, dry hydrogen should be used as the sintering atmosphere, the specimens being packed under powdered alumina. The addition of a small percentage of boron, titanium, or magnesia, with the object of reducing the amount of oxygen in the sintering atmosphere near the compact, prevents the sintering atmosphere from attacking the surface powders of the compact. In the case of the molybdenum borides, the purity of the atmosphere is not critical, owing to the volatility of molybdenum oxide at high temperatures.

(d) *Sintering Temperature*:—

In the case of titanium boride, pre-sintering is definitely helpful in reducing porosity before the final sintering, in which a liquid phase is present. Raising the sintering temperature also reduces the porosity but, at approximately 1400 to 1500°C, a point is reached beyond which any further increase in temperature causes coarsening of the boron grain size.

Too low a sintering temperature, in the case of aluminium boride, tends to facilitate the production of "clustering" of the bond, a phenomenon similar to the "cobalt lakes" in carbide tool materials. Temperatures above 1700°C appear to produce no improvement.

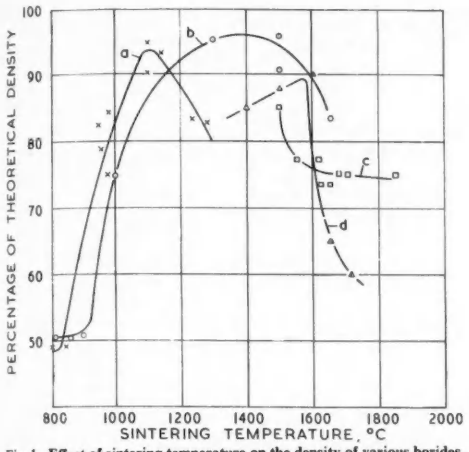

Fig. 1. **Effect of sintering temperature on the density of various borides.**
(a) 90% Mo_2NiB_2 — 10% CrB
(b) 90% CrB — 10% Ni
(c) Mo_2NiB_2
(d) 50% Mo_2NiB_2 — 50% Mo_2B

Molybdenum and chromium borides may be pre-sintered at about 800°C or fully sintered immediately. When they are pre-sintered, there is no shrinkage at the pre-sintering temperature, but an increase in density of some 15% occurs at the full sintering temperature. Fig. 1 shows the effect of sintering temperature on the density of various borides. For their final experimental programme on molybdenum borides, the American Electro Metal Corporation used sintering temperatures of the order of 1350 to 1400°C. Mention has already been made of certain difficulties in obtaining good reproducibility with hot-pressing but, in some cases, cold-pressing is not a satisfactory alternative; in such instances "warm-pressing" at about 600°C is often advantageous.

(e) *Variations in Composition*:—

Strictly speaking, this means variation in the percentage of bond metal, but this obviously cannot take place without varying the composition as a whole. The maximum hardness for titanium boride occurs when the nickel content is approximately 20% but, over the range of 5 to 25%, variations in nickel content do not appear to affect the properties of aluminium boride. The hardness of the iron-aluminium boride system is also high, some of the boride particles being as hard as tungsten carbide; in this system, however, the matrix tends to be brittle, its hardness and toughness depending on the composition and heat treatment.

The American Electro Metal Corporation, as part of their research contract, carried out a very systematic initial study of the molybdenum borides at all temperatures, but chromium boride was the only compound of the chromium-boron system which was investigated. Previous work had suggested the use of nickel rather than copper as a binder and, since nickel readily forms a number of borides, it was necessary to study the nickel-boron system before it could be said that the binary systems were known reasonably well. For reasons already discussed, it then became necessary to investigate the ternary systems Cr-Ni-B and Mo-Ni-B. Although no chromium-nickel boride has been used as a tool material, the eutectic composition (55% CrB, 45% Ni) has been employed as a binder for a ternary molybdenum-nickel boride.

Cutting Performance of Borides

It is difficult to make early comparisons between new and conventional tool materials, since optimum cutting conditions will not be the same. This is in the nature of a vicious circle, as it will not be known how far the actual cutting conditions fall short of the optimum until these optimum conditions are themselves known. It is thus imperative to place a very tentative interpretation on early test results showing a new material in an adverse light.

So far, the optimum cutting conditions for the various borides have not been fully evaluated, but a few general comments may be made. As with the oxide tools, high side-cutting-edge angles may have to be avoided, because the tools are to some extent susceptible to vibration. On the other hand, too low a value for this angle leads to early failure of the cutting edge, so that a compromise is inevitable. The range between 15 and 35 deg. appears to be suitable, the higher values being apposite to situations in which chatter is not anticipated. Slight positive rake angles may be employed, despite the weakness of the material when compared with earlier tool materials.

Following the same procedure as for the appraisal of aluminium oxide tools[1], consideration will now be given to four aspects of tool performance:—

(a) *Resistance to Wear*:—

The pattern of wear development is similar to that of other brittle tool materials, in that there is a fairly rapid wear rate for the first few minutes, followed by a decrease to some value which is maintained at a virtually constant figure for a reasonably long time, provided that cutting conditions are not too arduous. Eventually, wear rate increases considerably.

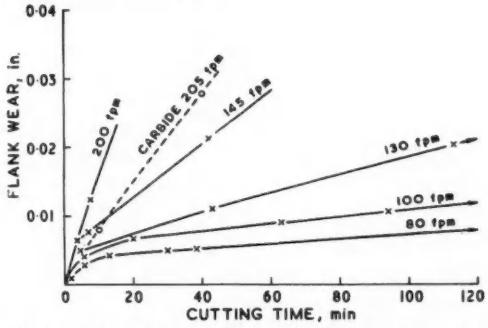

Fig. 2. **Flank wear as a function of cutting time at various cutting speeds, when machining cast iron.**

Fig. 2 gives a set of typical wear curves obtained when machining cast iron. It has been shown [14] that, for any tool material, there is an optimum of flank wear (before regrinding) for which the overall machining cost is a minimum. It has been further pointed out[15] that this optimum condition cannot always be achieved, because certain properties of the tool material may necessitate restricting the amount of flank wear to a value less than that corresponding to optimum conditions. Assuming a good boride tip, there appears to be no reason for imposing an unduly low limit on the amount of flank wear permitted before regrinding takes place.

Cratering is not normally serious with boride tools and, when machining steel, is less with a boride tool than with a steel-cutting grade of carbide.

(b) *Tool Life*:—

Unfortunately, of the principal geometric factors

governing tool life, only the effects of cutting speed have been studied. This is admittedly undesirable but, even in the field of carbide tool materials, with almost forty years of experience, there are astonishingly few data on the effects of feed and depth of cut.

Fig. 3 shows cutting speed plotted against tool life when turning a grey cast iron. It can be seen that, within the normal range of tool life, the performances of carbide and boride tools are comparable, though that of the boride is consistently lower; however, since the cutting speed is the same for a tool life of about 15 min, and the slope of the boride line is steeper, the boride performance relative to that of the carbide is better at the higher speeds. It should be stressed, however, that boride performance, like that of the oxides, is extremely susceptible to the variations in properties which will always occur unless the most rigid control is maintained in the manufacturing process. It can also be seen from Fig. 3 that the performance of the high-speed tool is not of the same order as that of the boride within the range of normal tool life.

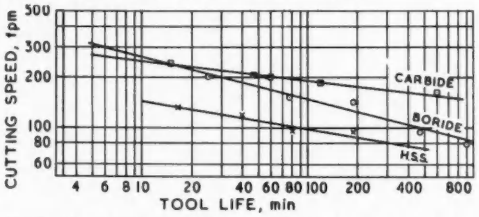

Fig. 3. Effect of cutting speed on the life of a carbide, boride, and high-speed-steel tool, when machining grey cast iron, using a depth of cut of 0·1 in. and a feed of 0·0104 in./rev.

Brass and aluminium have been cut with borides and, for chip areas of 0·1 in. × 0·01 in./rev. feed, there was no visible wear after 25 to 30 min within the range of cutting speeds from 400 to 700 fpm.

(c) *Power Consumed*:—

In the majority of cases, the power consumed when machining with boride tools is some 10% higher than with carbide tools, but some of the 90%Mo_2B-10%Ni tools exhibited increases of over 30%, compared with carbide. This is largely attributable to increased frictional effects between the chip and the rake face. Some idea of the increase can be gauged from the ranges of coefficients of friction for various tool materials given below.

Steel-cutting grade of carbide:— 0·84 to 1·09
90%Mo_2NiB_2-10% Cu:— 1·08 to 1·27
50%Mo_2NiB_2-50% Mo_2B:— 1·03 to 1·39
90%Mo_2NiB_2-10% Ni (hot-pressed):— 1·05 to 1·46
90%Mo_2NiB_2-10% Ni (cold-pressed):— 1·02 to 1·27

The cutting speeds at which the boride tools are used are not so much higher than the carbide speeds as to cause a great increase in shear-plane temperature and a consequent decrease in the shear strength of the material being cut; as a result, the part of the cutting force which contributes to the shearing of the metal is unlikely to change appreciably, and the increased frictional effect will be reflected by an increase in the cutting power.

(d) *Surface Roughness*:—

Tests conducted with boride tips show that cold-pressed tools give a consistently superior finish to that obtained with hot-pressed tools; indeed, there is more difference between hot- and cold-pressed tools than there is between different borides.

There is a relationship, in general, between surface roughness and the friction coefficient (i.e., the ratio of the forces along and perpendicular to the tool face), but the correlation coefficient is not high.

Brazing and Grinding of Tools

If it is not desired to use throw-away tips or slugs, boride tips may be brazed to standard steel shanks either with thin copper sheets or special brazing metals, but brazing is facilitated if carried out in a hydrogen atmosphere. Some work has been done with nickel- and copper-base brazing materials with promising results.

If tips are to be ground in the fully sintered condition, a diamond wheel, with a grinding speed of the order of 5000 fpm, is needed. A suitable wheel is a resin-bonded, 200–240 grit wheel. There are circumstances in which it may be desirable to grind in the pre-sintered state, in which case an ordinary green silicon carbide wheel is satisfactory.

Conclusion

It is now certain that borides can be developed for cutting-tool purposes, but there is much work yet to be done, largely in connection with the milling of the boride particles and the manufacturing procedure of the tips themselves. On the tool-engineering side, optimum cutting angles and cutting conditions require to be evaluated, but this will undoubtedly proceed at a much faster rate than was the case with carbides thirty years ago.

Acknowledgements

The author would like to express his thanks to the American Electro Metal Corporation, the Office of Naval Research, and the American Society of Tool Engineers for kind permission to quote from their reports.

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Extinction of A.C. Arcs by Lengthening in a Magnetic Field

By G. BÜCHNER. (From *Electrotechnische Zeitschrift* (*ETZ*), Vol. 80, No. 3, February 1, 1959, pp. 71–77, 14 illustrations)

By magnetically deflecting portions of an arc, so as to increase its length rapidly, arc voltage can quickly be raised to high values, causing rapid extinction of the arc. The work described in this article was undertaken as part of a programme for a new switching device, and details of the test equipment used and the results so far obtained are included.

INVESTIGATIONS into the problem of arc extinction in a.c. switching devices at low and medium voltages have shown that it is possible to use strong magnetic fields for rapidly increasing the length of an arc burning freely or confined between walls of insulating material. To provide a convenient method of striking an arc and providing the requisite magnetic field, special test equipment was constructed, comprising two electrodes located a suitable distance apart in both a vertical arrangement (Fig. 1a) and a horizontal arrangement (Fig. 1b). Each electrode consists of a hollow, insulated iron magnet body or core (5) with a narrow slit on one side, parallel to its main axis, and an "arc-runner" in the form of a metal bar (1) situated in the space provided in the slit section. This bar is in series with one or more turns of the supply cable (4), forming an exciter winding around the magnet body, so that the magnet is excited by the current producing the arc. In the vertical arrangement, an insulating partition (3) prevents short-circuiting between the individual arcs formed between each of the two bars and the corresponding arm of the contactor (2). This partition is not needed in the horizontal arrangement.

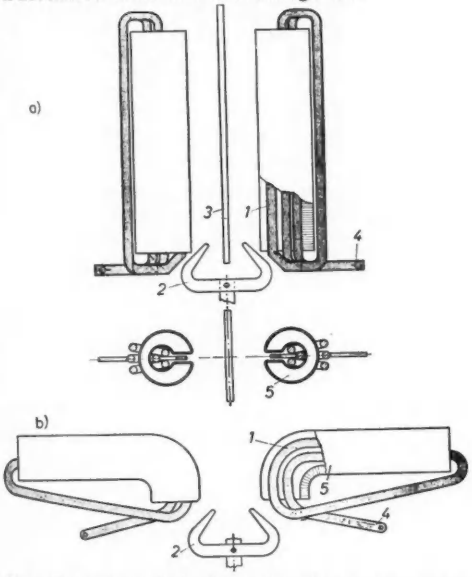


Fig. 1. **Test equipment for lengthening the arc by means of a magnetic field, showing (a) a vertical and (b) a horizontal arrangement.**

When arcing is initiated by moving the contactor (2) to break contact between the contactor arms and the bars (1), two separate arcs are initially formed. Then, as the self-excited magnetic fields drive the points of the arcs on the bars upwards, the points on the yoke arms of the contactor (2) move correspondingly inwards towards their free ends, until, finally, a single arc is formed which burns between the two main bars.

The arc current flows from the bar into the exciter winding of the magnet body. This winding is connected to the bar in such a way that the currents in the bar and in the portion of the winding situated in the iron body are in the same direction, increasing the magnetic flux and the induction in the air-gap. The force per unit length P acting on the portions of the arc situated in the air-gap can be expressed as IB, where I is the arc current, and B the flux density. The length of the arc is increased by its displacement from the bottom end of the bar. The arc

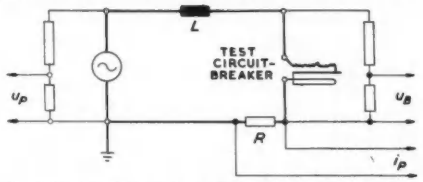


Fig. 2. **Schematic diagram of a simple inductive test circuit for investigating arc travel.**

then burns along the bar, but at a certain distance from it, because the magnetic force between the arc and the bar, intensified by the magnetic field of the air-gap, causes an outward deflection of the arc.

EXTINCTION PROCESS WITH A RAPIDLY EXTENDED ARC

The rapid extension of the arc due to current interruption can be obtained in various manners. However, in all arrangements previously used for this purpose, a rapid rise in arc voltage is of decisive importance. To explain this further, consider a simple inductive test circuit, such as that shown in Fig. 2, in which the ohmic resistances can be disregarded. The circuit is used to investigate a switching device giving an arc which is rapidly extended in length. A schematic oscillogram of the extinction test is given in Fig. 3.

In this diagram, separation of the contact pieces occurs at an instant t_T. The curves of test voltage u_P and arc voltage u_B are plotted to the same scale over a common base-line for zero voltage, so as to show comparative magnitudes. In the lower part of the diagram, the uninterrupted current is denoted by i_P, and the current after the arc is produced by i_L.

The arc voltage u_B rises in accordance with the increase in arc length, and this rise is assumed to be ap-

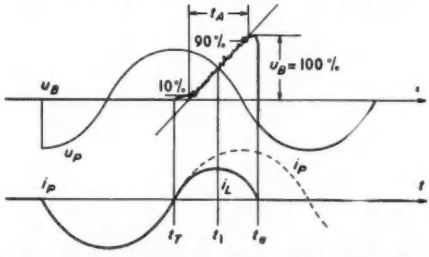


Fig. 3. **Schematic representations, based on oscillograms, of curves of current and voltage during the extinction of an arc rapidly increasing in length.**

proximately linear, corresponding to the desired conditions. The steepness of this voltage rise is given by $\sigma_{uB} = u_B/t_A$, where t_A is the duration of the rise in arc voltage. Increasing linearly, the arc voltage reaches the value of the driving voltage at the time t_1.

The equation of the test circuit is

$$u_P = L(\mathrm{d}i/\mathrm{d}t) + u_B + iR$$

where $iR = 0$, since ohmic resistances can be neglected. Since $u_P = u_B$ at the time t_1, the derivative $\mathrm{d}i/\mathrm{d}t$ must be zero at this instant, so the curve of arc current has a maximum at this position. The arc voltage continues to increase until arc extinction occurs at the time t_a, and then drops to a negative value. Whether this exceeds the corresponding value of the driving voltage and how the oscillation varies under different conditions will depend to a considerable extent on the extinction point t_a. However, it can safely be assumed that this transient is aperiodic because, after extinction of the extended arc, the residual conductivity of the path decreases fairly slowly, much more slowly, for instance, than in the case of an extinction enforced by a flow of quenching medium.

The arc current i_L deviates from the test current i_P to an increasing extent after the instant t_T, when separation of the contacts occurs. Falling off of current as a function of time, and the resulting distortion of one half-cycle of the sine-wave, depend on how rapidly the magnetic energy from the test circuit can be dissipated in the arc. The ohmic resistances of the test circuit are again assumed to be negligible. Thus, the return of the current to zero can be made to take place so early that it will coincide with the passage of voltage through zero, or even before.

The current variation can be calculated from

$$u_P = L(\mathrm{d}i/\mathrm{d}t) + u_B$$

or, with $u_P = u \cos \omega t$ and $u_B = \sigma_{uB}\,(t - t_T)$,

$$L(\mathrm{d}i/\mathrm{d}t) = u \cos \omega t - \sigma_{uB}(t - t_T)$$

so that, after integration,

$$LI = (u/\omega) \sin \omega t - \tfrac{1}{2}\,\sigma_{uB}(t - t_T)^2$$

The integration constant is zero. By means of this relation, the variation of current can be plotted for various steepness values σ_{uB} for the rise in arc voltage. For simplicity, it is convenient to put $t_T = 0$, but other values of t_T can also be taken into account in the graphs. If the arc-voltage drop is not sufficient to cause extinction after the first half-wave, restriking of the arc will occur, with a trapezoidal (negative) variation in voltage and a distorted negative half sine-wave of reduced amplitude for current.

Now, it can be seen from the above expression for LI that the duration $(t - t_T)$ of the arc is strongly dependent on the value of σ_{uB}, i.e., the steepness of the arc-voltage variation. A steep voltage rise will reduce the duration of the arc (i.e., the time required for the current to return to zero). If the arc voltage is higher than the instantaneous value of the test voltage when the current passes through zero, it may be assumed that extinction is obtained; if not, restriking will occur and will extend over another half-cycle of current.

The energy A dissipated during circuit-breaking is

$$A = \int iu_B \,\mathrm{d}t$$

the integration being from t_T to t_a. With oil circuit-breakers, air-blast circuit-breakers, etc., the endeavour is to obtain a small value for this expression by maintaining the smallest possible values for arc voltage. Such circuit-breakers give a peak value of arc current which is hardly different from that of the test current which would flow if the contact pieces remained closed. The duration of the half-wave of current is then also approximately equal to that of a full half-cycle.

The use of very high arc voltages also gives values of energy dissipation of similar magnitudes, however remarkable this seems at first. By driving the arc voltage upwards to very high values, the arc current can be reduced to a considerable extent, and, moreover, the duration of the arc will thus be only a fraction of that of a normal half-period.

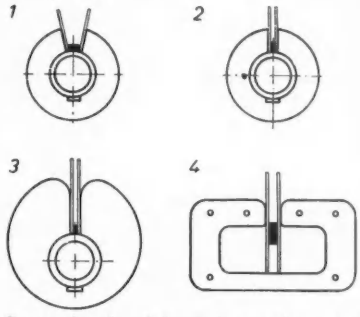


Fig. 4. **Cross-sections through four basic types of magnet electrodes.**

As regards electrical loading on the components, it should be noted that the rapidly moving arc traverses very large areas during its burning period, so that the energy per unit area that the insulating parts are called upon to sustain is only a fraction of the total load. For instance, even with an arc travelling at a speed of only 100 m/sec and an arc-voltage drop of 20 V/cm, the surface load per square centimetre, with a current of 10 kA, would amount to about 0·02 kWsec — a very small value indeed.

Summing up, it can be said that interruptions of current in a.c. circuits by means of an arc which is very rapidly increased in length have the following characteristic features:—

(1) Rapid rise in arc voltage to high values.
(2) Considerable reduction in arc current (below the corresponding values of the test current), the reduction being dependent on the steepness of the arc-voltage rise.
(3) Considerable reduction in arc duration, in comparison with the duration of a normal half-wave, this reduction also being dependent on the steepness of the arc-voltage rise.
(4) Easier extinction when zero current is reached at about the same instant as voltage passes through zero, also improved by a steep rise in arc voltage.
(5) Energy dissipation which is dependent on the steepness of the arc-voltage rise.

Experimental Investigations

Various experimental arrangements with the basic features described were investigated. In addition to the usual oscillograms, high-speed cinematographic recordings of travelling-arc phenomena were taken in each test, using equipment which permitted an exposure of about 5 microseconds, at intervals of 0·275 millisecond. Special equipment was used to determine the positions at which re-ignition of the arc occurred, and the results were also recorded in oscillograms.

Basic Types of Magnet Electrodes

The magnet body, i.e., the hollow iron core with a slit in which the bar used as an arc-runner is situated, can be either a solid or a laminated assembly. It was, however, found that eddy currents tended to retard arc travel in the case of solid cores. Consequently, all test electrodes were built up from laminations.

The effective iron cross-section of the magnet body cannot be made arbitrarily large, in view of weight considerations for circuit-breakers. However, improved performance can be obtained by providing an air-gap of suitable shape. Of the four arrangements shown in Fig. 4, type (2) with a parallel narrow air-gap provided the highest speed of arc travel and the steepest rise in voltage, but is not necessarily the most favourable in all circumstances. Thus, for example, in tests with arc currents between 0·25 and 4 kA and voltages of 0·5 and 2 kV, type (3), which also has a parallel narrow air-gap, gave a somewhat lower speed of arc travel and less steepness of rise in arc voltage than type (1). For each arrangement of air-gap, there is an optimum position for the bar. For example, in the case of type (4), which provided a steepness of rise in voltage second only to that of type (2), it was found that the bar should be located slightly under the air-gap, approximately as indicated.

For generation of the necessary magnetic flux, the exciter winding must be designed with a certain number of turns. One turn is already provided by the bar inside the core and by the arc itself. Now, although it is immaterial whether the flux is generated by a strong current in a single turn or by a correspondingly weaker current in several turns, the action of the magnetic force in the air-gap depends not only on air-gap induction (i.e., the flux of the magnetic circuit), but also on the product of the current in the path and the induction. Thus, equally rapid displacements of the arc were obtained, for instance, for an arc current of 2 kA without an additional exciter turn and for a current of 1 kA with three additional exciter turns.

If the increase in length of the arc as a function of current is assumed to be based only on the relation $P = IB$ for the force acting on a current-carrying conductor, then, in the range of very small currents with induction increasing proportionally to the flux, lengthening of the arc would be approximately proportional to the square of the arc current. For very large currents, on the other hand, assuming that induction remains constant with increasing flux, the relation would have to be approximately linear. From the tests on the four basic electrodes shown in Fig. 4, it was established, however, that the increase in length of the arc was less rapid than the corresponding increase in current.

The reasons for this noticeable retardation of arc movement have not as yet been clarified, although various attempts have been made to explain it, e.g., by taking air resistance into account. It would appear, however, that for practical purposes the only way of finding the relationship between lengthening of the arc and arc current is by means of actual tests.

The driving voltage has no direct effect on the rate of increase in arc length, but influences it indirectly. With increased voltage, the arc must be drawn out to a greater length before extinction occurs and, because of the increased difference in potential, re-ignition may take place, tending to slow down the rate of increase in arc length. In tests, however, this influence became noticeable only at voltages above 2 kV.

Extensive tests were also carried out with other arrangements of magnet electrodes. Of these, two arrangements, differing somewhat from the basic designs previously considered, were electrodes with subdivided bars and electrodes with transverse deflection, described below.

Magnet Electrodes with Subdivided Bars

In order to obtain a sufficiently strong flux with small currents, several turns are required for the exciter winding. There is a continuous flow of current through these turns if the original arrangement is retained. Another possibility (Fig. 5) is provided if the switching arrangement is made with a main contact (4) and an arc or follow-up contact (3) in such a way that the auxiliary winding is in circuit when the main contact is opened. However, during current reversal, a voltage drop is produced in the auxiliary winding and may lead to the formation of an arc at the main contact. This winding should therefore be closed only after the arc contact is opened. In the arrangement shown in Fig. 5, this is achieved by means of the arc itself. The bar (1) is divided into two parts connected to the exciter winding (2) with one or more turns. During its travel, the arc traverses the break in the two portions of the bar and, when the arc reaches the second portion, the arc current begins to flow through the auxiliary winding, which cannot immediately receive the total current from the supply line (5), so that the current rises gradually. During this very brief period, the arc cannot travel on at the same speed, so that the delay must be made as short as possible.

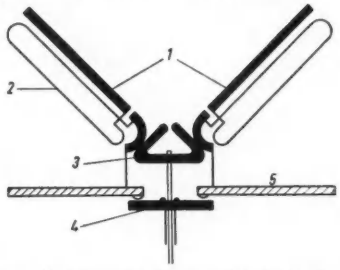


Fig. 5. Schematic arrangement of a magnet electrode with subdivided bars.

By determining experimentally the most favourable spacing of the two electrodes in the vertical and horizontal directions, it was found possible to reduce the delay to a small value. The main factor determining the current rise, however, is the magnitude of the inductance of the additional winding, i.e., the number of turns in the exciter, and it was found that optimum results are obtained with only one turn per interruption; if several turns are necessary, the bar must be divided into a corresponding number of parts. Tests showed, however, that, to avoid increasing the delay period by frequent re-ignitions, the bar should not consist of more than two or three parts, and that the spaces between them should not be too small.

Magnet Electrodes with Transverse Deflection

The arc can be displaced in both the longitudinal and the transverse directions by means of an arrangement such as that shown in Fig. 6. Longitudinal movement is produced by means of normal magnet electrodes (4) and transverse movement with a transverse deflector (2), also made up of laminations. The magnet electrode is situated in a recess in the lower portion of this deflector, and is arranged so that its exciter winding (5) will also energize the deflector. The magnetic field thus produced

in the air-gap of the deflector drives the portion of the arc situated in this gap upwards, away from the magnet electrode. The contact point of the arc on the bar of the magnet electrode also moves while transverse deflection takes place.

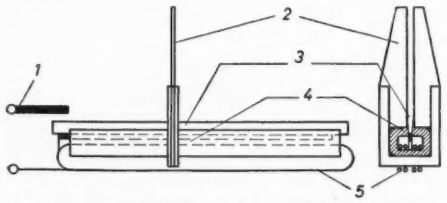


Fig. 6. **Schematic arrangement of a magnet electrode with transverse deflection.**
(1) Counter-electrode. (2) Transverse deflector. (3) Insulating walls. (4) Magnet electrode. (5) Exciter winding.

This displacing of the arc by transverse motion was found to be a very effective means of reducing tendency to re-ignition at high voltages. Moreover, with combined transverse and longitudinal movements, a greater rate of increase in arc length per unit of time was obtained, amounting to about 1·3 times as much as that produced by simple longitudinal movement. It was not possible to exceed this value, irrespective of the height of the deflectors or their number.

Experimental Circuit-Breaker

The basic types of magnet electrodes were tested in an experimental circuit-breaker to determine their suitability for switching equipment. For contacting, a synchronously-driven yoke-type contactor was used, which could be accurately set to the required phase angle for circuit-breaking and arc generation. The main features of this circuit-breaker are shown in Fig. 7, in which arrangement (b) with the arms bent upwards was designed to as to reduce the amount of space required. This arrangement has been found practicable for voltages exceeding 4 kV, but it can take currents up to 1 kA only because, with greater currents, accumulations of gases generated by the arc occur in the angles of the electrodes, with considerable re-ignition.

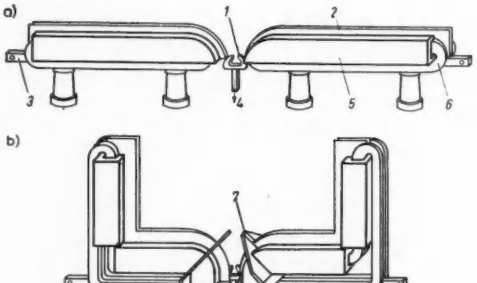


Fig. 7. **Experimental circuit-breakers, (a) with horizontal magnet electrodes, and (b) with angled magnet electrodes.**
(1) Arc contact. (2) Insulating walls. (3) Current supply. (4) Contactor. (5) Magnet body. 6) Exciter winding. (7) Transverse deflector.

Switching tests with voltages up to 6·9 kV and currents up to 6 kA, using the arrangement shown in Fig. 7a, yielded satisfactory results, typical values for extinction times being 3 to 6 milliseconds for currents from 2 to 6 kA and voltages from 0·3 to 4·8 kV, 5 to 25 msec for currents of 200 A and voltages from 0·3 to 6·9 kV, and 9 to 40 msec for currents of 20 A and voltages from 0·3 to 4·5 kV.

These test results show that short extinction times are obtained with high test currents, whereas the time required increases considerably for very small currents, this disadvantage being common to all circuit-breaking arrangements with purely magnetic means of arc extinction. However, by supplementing magnetic extinction with a weak air blast, rapid and reliable interruption of even very small currents can be obtained fairly simply.

Some additional tests were carried out at voltages of 2 kV and currents up to 30 kA, the extinction time at 30 kA being 2·8 msec. In all tests, the contacts were set so that separation would occur approximately when passing through zero current. If separation takes place shortly before the passage of current through zero, the extinction times are increased by about 15%. For all other settings, the times are shorter, so that the times given above are approximately the maximum extinction times for single-pole tests.

European Developments in Experimental Stress Analysis

(*Concluded from page 195*)

is permissible, and the same transducer head can be used for various measuring ranges from 1 to 10^4 microns full-scale deflection.

Registration is often more valuable than visual indication, and visual meters are threefore provided with attachments for registration; for instance, an inductive pick-up connected to the free end of a Bourdon tube permits recording of pressure or force (Belgium), while mechanical contact extensometers, capable of giving either continuous registration or twelve threshold values, with contacts spaced to indicate every 10^{-5} in. or more, have been built in Germany.

For vibration problems, a powerful mechanical low-frequency vibration exciter, giving a 5-ton unbalanced force at 20 to 10 cps for use on ships was described (Holland). Also, since dangerous vibrations are usually connected with the natural frequencies of machine components and it would therefore be an important aid to design if the amplitude of the response of such components to excitation of constant strength at varying frequency could be analysed directly from measurements under service conditions, a system for the excitation and analysis of response amplitudes over a given range of frequencies has been developed by a Danish firm as a " frequency-amplitude analyser " and has been used on the connecting rod of a one-cylinder internal combustion engine.

Amongst other equipment described, a Dutch transistorized strain indicator, measuring 8 × 4 × 2 in. and weighing 2 lb, may be mentioned. This indicator works on the principle of a carrier-wave-fed double-bridge system, the voltage difference after amplification and rectification being read off a moving-coil meter or compensated by a potentiometer mechanically coupled to a digital counter. In addition, an electronic d.c. to a.c. converter circuit supplied from a 24-V battery and giving 300 V a.c. output for electronic amplifiers is being used in German aircraft research, while, in various Dutch papers, two systems for automatic or semi-automatic registration of results on a chart, an electric typewriter, or a punched tape, were presented, and the possibilities of storage of measured results on magnetic tape discussed.

U.S.A.

An Instrument for Measuring Pore-Size Distribution by Mercury Penetration

By N. W. Winslow and J. J. Shapiro. (From *ASTM Bulletin*, No. 236, February 1959, pp. 39–44, 6 illustrations)

While the need for defining the pore structure of many technologically important materials, such as filters, separators, and catalyst carriers, has become generally recognized, the use of the method of mercury intrusion appears to have been limited to a relatively few researches, where the need or magnitude of the project has justified the effort and expense of specialized equipment.

Recent progress in various fields of technology has made it a matter of practical importance, as well as of scientific interest, to know both the size and the volume of the voids in porous materials. Among the available methods for analyzing pore spectra, the method of mercury penetration has been applied chiefly to the range of small pore diameters, i.e., below 1 μ, although it is generally recognized that the method should be applicable to pores of several or many microns in diameter. Heavy apparatus has been required to withstand the high pressures, and volume readings have generally been made by indirect methods. Thus, it often has been the cost, availability, and difficulty of manipulation of apparatus which have placed a practical limitation on the more general use of mercury intrusion.

In undertaking the present investigation, it was believed that high pressures of several thousand pounds per square inch could be handled safely and efficiently in transparent chambers of moderate weight. On the other hand, it was considered that, while such pressures would permit measurement of diameters well down in the submicron range, a general-purpose instrument should also be capable of operation at low pressures to make possible the determination of pore sizes of several microns, considered characteristic of many important materials. Finally, it was hoped that techniques could be perfected whereby all porosity could be identified as coarse or fine, even though its size fell outside the pressure range of the instrument.

To this end, the prototype instrument shown schematically in Fig. 1 was constructed. It consisted of a heavy-walled glass pressure tube *D*, with movable closures *C* and *F*, capable of holding the required pressure, and of the calibrated penetrometer *E*, which could be placed within the pressure tube for observation during pressurizing in steps. The threaded port *H* through the centre of the bottom closure was connected to a system consisting of a valved vent for relieving pressure, a pressure source, and gauges for measuring the pressure increments.

Pore analysis consisted of the following procedure: First, a sample of suitable size was placed within the ground-glass joint *G* of the penetrometer, and the meter was placed in a filling device connected to a vacuum system and a means of introducing mercury. After pumping off air, a quantity of mercury, slightly more than enough to fill the penetrometer, was admitted to immerse the tip of the penetrometer in a pool of mercury in the bottom of the filling device. Admission of atmospheric pressure then caused the penetrometer to fill, immersing the sample without exposure to air.

The filled penetrometer was then removed from the filling device and placed in the instrument. Pressure was admitted in a stepwise manner up to about 600 psi, the smaller pores being filled progressively as increments of pressure were applied. At each selected pressure level the mercury level was read on the calibrated stem of the penetrometer, and the volume of pores in a given size interval was thus directly determined as the difference in reading of the penetrometer before and after application of the appropriate pressure increment. No corrections for distortion were required, since the penetrometer was subjected internally and externally to the same pressure. The entire procedure required about twenty minutes.

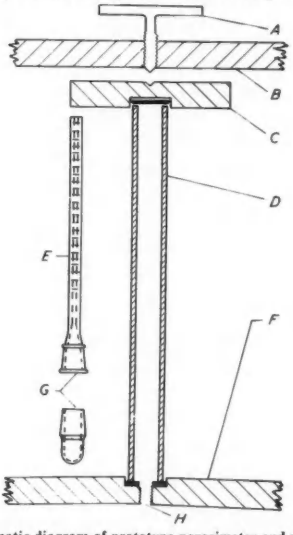


Fig. 1. **Schematic diagram of prototype porosimeter and penetrometer.** (*A*) Hand screw. (*B*) Yoke. (*C*) Upper closure. (*D*) Glass pressure tube. (*E*) Calibrated penetrometer (*F*) Lower closure. (*G*) Glass joint. (*H*) Threaded port for connection with pressure sources, gauges, and vent.

At the point where the filled penetrometer is placed in the porosimeter, the mercury occupies the total volume of the penetrometer, except for the displacement by the sample. The actual displacement is less than the apparent volume of the sample by any pore volume that may be penetrated by the mercury under the applied pressure at the time the total mercury in the penetrometer is determined. In the procedure described, pores of 10 μ diameter or greater are filled under the applied pressure of 18 psi (15 psi atmospheric plus 3 psi mercury head in the calibrated stem) at the time the penetrometer is placed in the instrument.

By use of this relationship, pores which may be present outside of the range of the instrument, in this case 10 to 0·3 μ, can be identified as greater than 10 μ or smaller than 0·3 μ by the addition of one more operation to the procedure. If the penetrometer, which is designed for manipulation on an analytical balance, is weighed after filling, the contained weight of mercury, and hence its volume, can be obtained by subtracting the weight of the empty penetrometer and the sample. Subtraction of the contained volume of mercury from the volume contained in the absence of a sample, determined by calibration of the penetrometer, gives the actual displacement of the

sample. The amount by which the displacement is less than the apparent volume of the sample is the volume of pores greater than 10 μ in diameter.

If the total pore volume of the sample is known, e.g., from real and apparent densities, the volume of pores smaller than 0·3 μ can be calculated by obtaining the summation of the volume greater than 10 μ, and all increments of penetration read directly over the range 10 μ to 0·3 μ. This summation, i.e., the volume of pores greater than 0·3 μ in diameter, subtracted from the total pore volume of the sample, gives the volume of pores smaller than 0·3 μ. For these calculations, apparent density is preferably determined by accurate measurement of the dimensions of a sample of regular geometric shape.

Calculations and Theory

The theoretical basis for the mercury-penetration method is negative capillarity. In any system consisting of a porous solid and a non-wetting liquid, there is a repulsion of the liquid from the surface of the solid. Pressure is therefore required to cause the liquid to enter any pore, and the pressure required is greater as the pores become smaller. It can be shown that the following relation exists between pressure and pore size:—

$$D = \frac{-4\sigma \cos\theta}{p}$$

where D is the diameter of the smallest pore filled at a pressure p, σ is the surface tension of the liquid, and θ is the wetting angle.

For the purpose of this investigation, σ was taken as 473 dynes/cm, and θ was considered to be 130 deg. Both values were assumed to remain constant over the entire range of pressure. The small compressibility of mercury is negligible over this range and could be ignored at much higher pressures, unless extreme accuracy were sought or materials of very low total porosity were studied.

It is desirable, in the interest of estimating errors resulting from the several assumptions on which the accuracy of mercury porosimetry depends, to obtain reference standards in several ranges of pore size. Of the possible methods of obtaining these, machining operations are practical only in a range of pore sizes considerably greater than any which has been so far covered by porosimetry. However, extension of the method into the range where machining is applicable has proved successful.

Self-Contained Hydraulic Instrument

For many routine determinations of pore structure, it is desirable to have an instrument capable of measuring pore diameters well below the 0·3 μ limit of the prototype instrument described above. Moreover, the instrument should also provide measurements in the range above 10 μ, where the structure of many filters, battery separators, and other materials is to be found. To obtain the desired range extension in both directions, to avoid the hazard inherent in using a gas system, and to provide features of convenience lacking in the prototype, a hydraulic instrument was developed.

Basically, both the design and method of operation are similar to those of the prototype instrument. The simple glass pressure tube is replaced by an armoured tube of the boiler-level type, mounted on a pressure vessel which can be closed without the use of wrenches. Within these pressure elements rests a penetrometer, essentially similar to that shown in Fig. 1.

Hydraulic fluid, preferably ethyl or propyl alcohol,

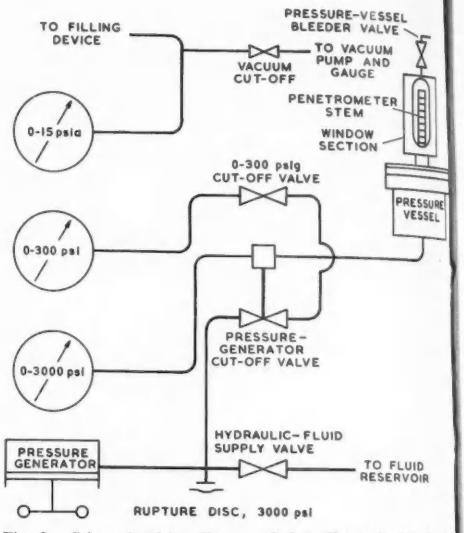


Fig. 2. Schematic piping diagram of the self-contained hydraulic porosimeter.

is supplied from a levelling bottle, connected as shown in the piping diagram in Fig. 2, so that the entire system can be filled or emptied in about two minutes. The system includes a screw-type, hand-operated pressure generator. This device eliminates the need for an auxiliary pump or gas cylinder, and its high leverage provides very precise control of pressure with a minimum of effort.

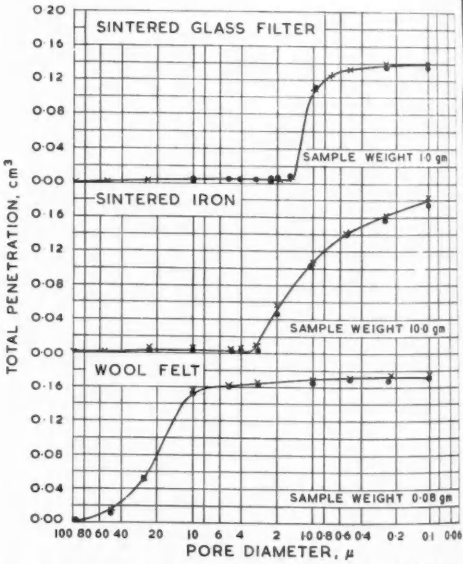


Fig. 3. Pore spectra of three materials, obtained with the hydraulic porosimeter.

An added feature of the hydraulic instrument is a means of operating at sub-atmospheric pressure. This consists of a third gauge that will indicate pressures

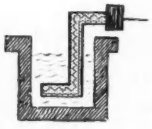
(*Concluded on page 218*)

Resistance Heating – 2

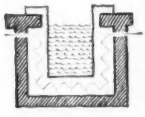
Electric resistance heating elements have been briefly described in Data Sheet No. 4, with two examples (in furnaces and ovens) of their application in industry. This sheet lists some of the further applications which can be effectively dealt with by resistance heating.

Soft Metal Melting

Electric resistance melting is most commonly used for lead, tin, zinc, antimony, aluminium and their alloys – in processes such as tinning, type-casting, die-casting and lining bearings – at temperatures of up to around 800°C.



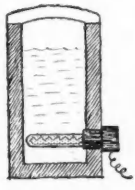
In most cases, sheathed elements are immersed directly in the metal, a more efficient method than applying heat to the outside of the containing vessel or pot. Immersion heating simplifies the application of lagging to the outside of the vessel, reducing heat losses and current consumption to a minimum. The elements are usually positioned near the inside wall of the vessel, leaving plenty of working space, but in a few cases, where the full volume of the pot is required, or where the metal to be melted is particularly corrosive, the elements are positioned outside the pot, often in contact with it.



In all cases, the precise temperature control that is so essential in soft metal processes is readily achieved by the use of electricity, and electric heating also leads to a reduction of casting rejects and metal wastage and a marked improvement in working conditions.

Liquid Heating

Electricity provides the ideal way of heating liquids such as water, oils, varnishes, plating, photographic and other solutions, and of melting and heating waxes and compounds, glues and pastes, tars and bitumen. Again, immersion heating is the method most commonly employed, but considerations of space or the nature of the liquid may sometimes necessitate the use of external heaters. Several types of devices are available to give precise and automatic temperature control, and lagging is again commonly applied to the vessel to minimise heat losses.

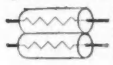


Fire hazards associated with inflammable liquids are invariably reduced by electric heating, particularly if immersion heaters are used.

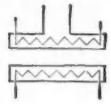
It is usually possible without difficulty to apply electric heaters, either immersion or external, to existing vessels.

Platen, Press and Roll Heating

Electricity offers the simplest and most convenient method of heating platens, dies and rolls. It gives the precise temperature-control characteristic of electric heating systems, with lower maintenance costs. Moreover, the relatively high temperatures required in some processes for maximum working speeds are reached without difficulty. Flexible electrical connections to moving parts give far less trouble than flexible pipe connections carrying hot water or steam.

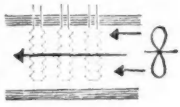


When electric heating is used, one or more presses can be operated without the necessity of keeping a boilerhouse staff at work.



Air Heating

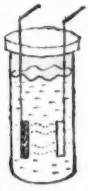
Streams of air, and of many other gases, can be heated most efficiently by electric resistance elements disposed across the duct leading to or from a fan. Heat is generated only inside the duct, just where it is required, and none is carried away through exhaust flues or pipes. Quick rise of temperature and precise temperature control are assured when electric resistance air heaters are used.



Electric Steam Boilers and Steam Raising

There are many cases when the use of electricity for steam raising is fully justified on economic grounds.

The means employed for bringing steam from a boilerhouse to the point of usage are often extremely wasteful, but where electricity is used the steam can be generated on the spot and losses from steam mains are eliminated. The efficiency of the electric boiler normally exceeds 96% and is practically constant at all loads.



Plant requiring process steam can be equipped with its own electric steam boiler, freeing the working space of steam mains just as individual electric motor drives free the factory of masses of shafting and belt drives.

Even where boilerhouse steam is still used, it is sometimes desirable for best results to boost the steam temperature at the point of usage, to make up for transmission heat losses or to increase the superheat, and this function is most conveniently performed by an electric resistance heater inserted in the steam line.

For further information get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, W.C.2. Tel: TEM 9434.

Excellent reference books on electricity and productivity (8/6 each, or 9/- post free) are available – "Resistance Heating" is an example; "Induction and Dielectric Heating" is another.

E.D.A. also have available on free loan a series of films on the industrial use of electricity. Ask for a catalogue.

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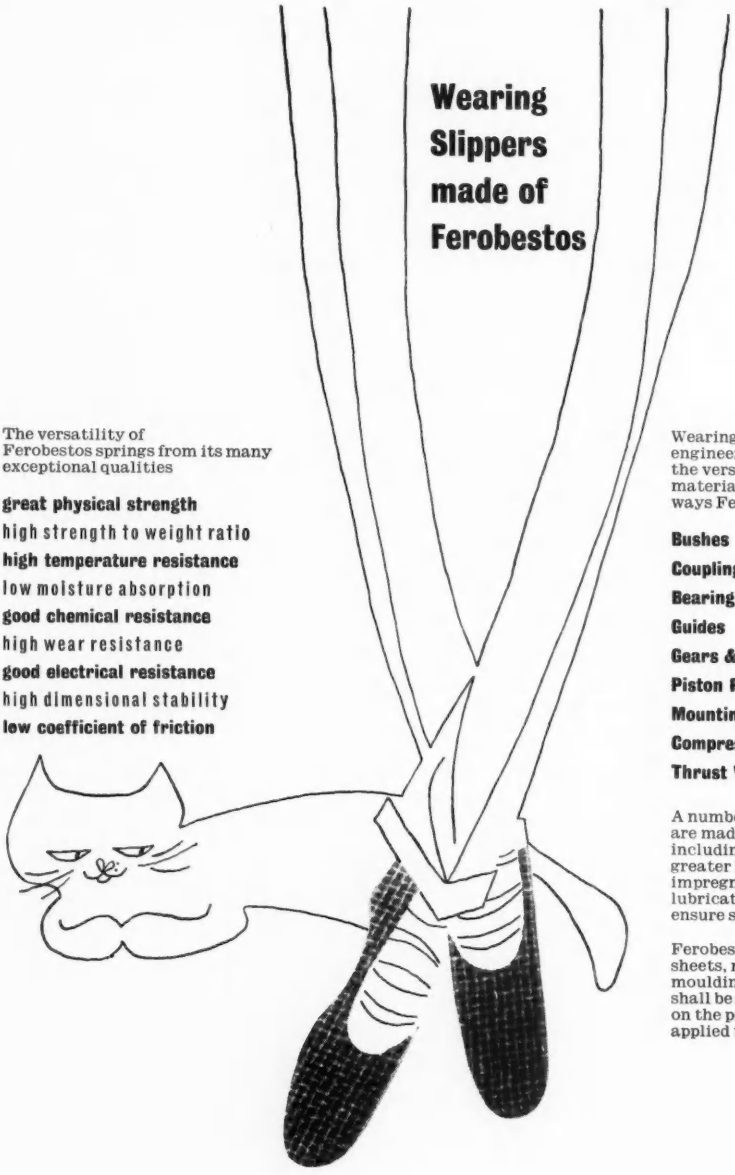
Wearing Slippers made of Ferobestos



The versatility of Ferobestos springs from its many exceptional qualities

great physical strength
high strength to weight ratio
high temperature resistance
low moisture absorption
good chemical resistance
high wear resistance
good electrical resistance
high dimensional stability
low coefficient of friction

Wearing slippers is only one of the engineering applications of Ferobestos—the versatile, asbestos-reinforced plastic material. Here are just a few more of the ways Ferobestos can be used:—

Bushes
Coupling Discs
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Piston Rings
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A number of special grades of Ferobestos are made for particular applications including silicone impregnated for greater heat resistance, and graphite impregnated for more efficient lubrication. Ferobestos gear wheels ensure silence in operation.

Ferobestos can be supplied from stock in sheets, rods, and tubes. Special mouldings can be made to order. We shall be glad to recommend and advise on the possibilities of Ferobestos as applied to any particular industry.

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British Industrial Developments

Small General-Purpose Vacuum Furnaces

A new, small general-purpose vacuum furnace, suitable for research work or for small-scale pilot production, is now being constructed under an agreement recently completed between The General Electric Co. Ltd. and Vacuum Industrial Applications. This furnace makes it possible to cover with a single unit a wide range of vacuum-heating processes, including sintering and outgassing. Furthermore, melting, casting, and general heat treatments can be carried out in a high vacuum, using either resistance or induction heating. A general view of the furnace is shown in Fig. 1, while Fig. 2 shows the interior arranged for induction heating, with the crucible and mould surmounted by the charging buckets.

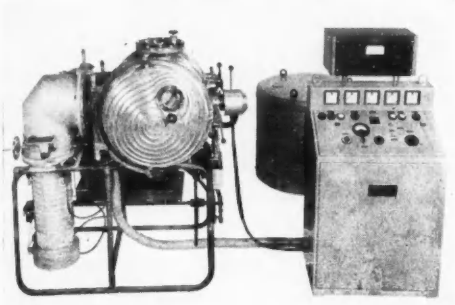


Fig. 1.

Ease of operation is ensured by the use of simple vacuum, mechanical, and electrical controls. The chamber, of 24 in. i.d., is clad with stainless steel, facilitating cleaning and reducing outgassing, and externally operated handling gear is fitted for making additions to a melt, for taking measurements of temperature, and for tilting the crucible. A window is provided at the top of the chamber to enable the progress of a melt to be observed, while internal handling mechanisms can be viewed through a window in the chamber door.

Graphite, tantalum, tungsten, or molybdenum can be used for the resistance heaters, depending on the particular process and specified vacuum. With a refractory crucible, temperatures of from 1200 to 1400°C can be achieved, or up to 1800°C with a graphite crucible. In the induction-heating versions, a 10-kW, 10,000-cps generator is used, giving temperatures in excess of 1700°C in the charge for melting. When the sintering assembly is used, the power is absorbed in a graphite susceptor, where temperatures of more than 2400°C can be obtained.

A two-stage high-speed pumping system is used to evacuate the furnace tank, a vacuum of the order of 10 to 5 mm Hg being possible. Short pumping cycles can be achieved, and the furnace will operate satisfactorily, despite the severe outgassing occurring in some processes.

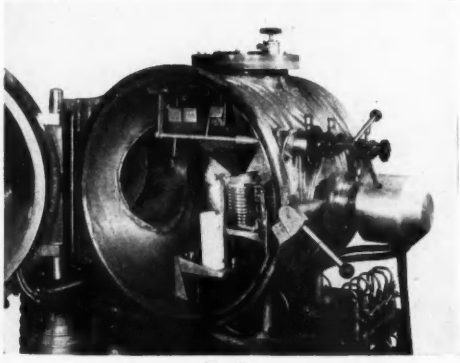


Fig. 2.

Resin-Bonded Dispersions of P.T.F.E.

Stated to represent a significant advance in the technique of dry film lubrication and surface coatings, a range of resin-bonded dispersions of P.T.F.E., first marketed in the U.S.A. last autumn, is now being manufactured and marketed under licence from E. I. Du Pont de Nemours & Co. under the name of "Emralon" by Acheson Colloids Limited, of Richmond, Surrey. The major advantages of these dispersions over pure films of P.T.F.E. are that they can be applied to heat-sensitive surfaces, they exhibit improved corrosion resistance and adhesion, and the coatings produced are more wear-resistant.

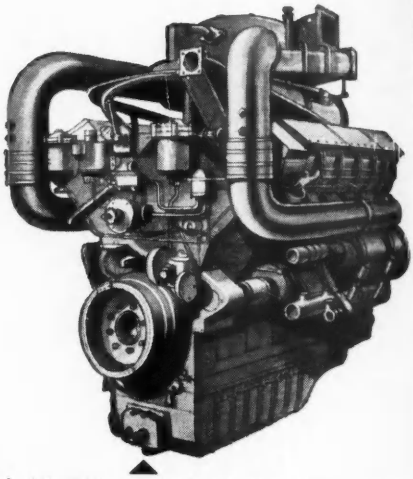
At present, two dispersions are available, i.e., "Emralon 810" and "Emralon 820". Of these, "Emralon 810" is a pigmented coating, bonded with a phenolic-type resin, developed to provide a means of imparting the desirable surface characteristics of pure polytetrafluoroethylene to a wide variety of mechanical parts. The material is applied by air spray and requires curing for only 1 hr at 150°C. The green coatings produced are tough, flexible, adhesive, non-soiling, corrosion-resistant, and have remarkably low friction characteristics, combining the excellent adhesion and corrosion resistance of the phenolic resin with the low friction and good release properties of P.T.F.E. Thus, properly cured films of "Emralon 810" exhibit a significant improvement in wear life over fused P.T.F.E. films. Their friction coefficient is between 0·05 and 0·07, and they are capable of withstanding a temperature of 200°C for limited periods, or 175°C in continuous use. This dispersion can be applied to rubber, metal, plastics, and other materials which will withstand the necessary bake.

"Emralon 820" is a pigmented coating, bonded with a thermoplastic resin, which can be applied by spraying or dipping and which does not require heat-curing. Thus, it is especially suitable for application to surfaces which are too sensitive even for the low curing temperature of "Emralon 810", or for use where baking is impracticable. The turquoise-coloured coating produced hardens in air at room temperature in about 2 hr. The friction coefficient of the film is, as before, between 0·05 and 0·07. This dispersion can be applied to metals, plastics, and other substrates which are structurally rigid.

Mixing Unit for Emulsions of Soluble Oils and Water

Stated to overcome the difficulties inherent in the production of emulsions of water with soluble cutting oils or similar fluids, a new mixing unit, designated model 52MT, announced by Wakefield-Dick Industrial Oils Ltd., of London, W.1, uses air as the mixing medium. The unit basically consists of a 250-gal mixing tank sur-

MAYBACH POWER MADE IN BRITAIN

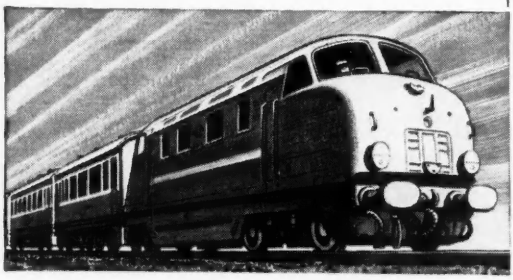


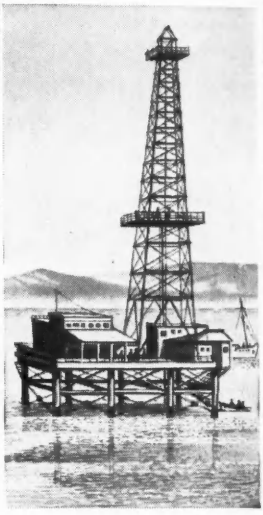
Typical of the MD range of engines is this Type 650 12-cylinder supercharged model with cylinders arranged in 'V' formation.

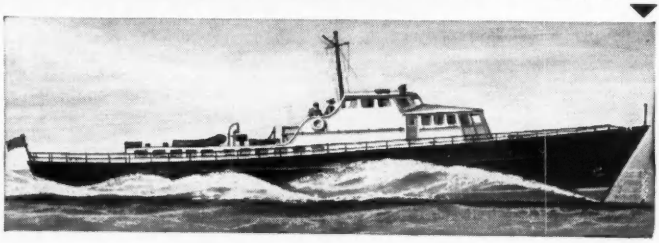
◀ Railway Traction 220-2,000 B.H.P.

Industrial Plant 220-1,750 B.H.P. ▶

Marine 220-3,000 B.H.P.



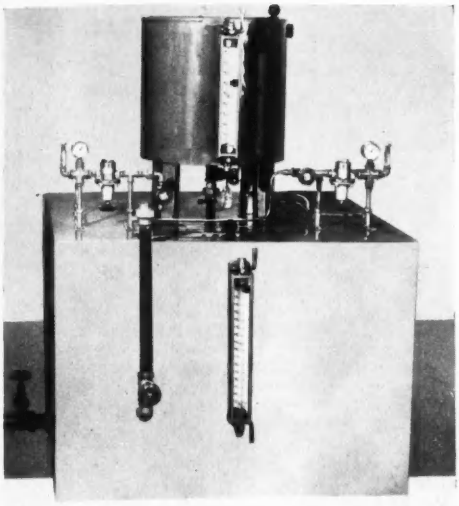




Bristol Siddeley have the exclusive manufacturing and selling licence in the United Kingdom for the world-famous Maybach MD range of In-line and 'V' form diesel engines. These diesels range from 4-cylinder engines of 220 hp to 16-cylinder engines of 3,000 hp. They have an outstanding record of performance and reliability over millions of miles on railways throughout the world, and are widely used for marine propulsion and industrial power generation of all kinds.

BRISTOL SIDDELEY Maybach **DIESEL ENGINES**

BRISTOL SIDDELEY ENGINES LIMITED, COVENTRY, ENGLAND



mounted by a 23-gal header tank, both tanks being fitted with graduated scales to ensure accurate measurements. The header tank can be filled either from portable containers or via a pipeline from remote bulk storage, and the inlet and outlet pipes of the mixing tank are provided with control valves. The air supply lines for mixing are also provided with control valves and, in addition, incorporate pressure gauges.

In operation, a measured quantity of soluble oil (or other fluid) from the header tank is sprayed over the surface of the water in the mixing tank by jets of air, and air also issues from pipes located near the bottom of the tank. The resulting agitation of the fluids ensures thorough mixing.

Heat-Resistant Polystyrene Materials

Two new heat-resistant polystyrenes, Styron 700 and Styron 440, are now being marketed by British Resin Products Limited, of London, W.1. Styron 700, a general-purpose grade, has the exceptional heat-distortion temperature of 106°C and is available in crystal and the full range of Styron colours, transparent, translucent, and opaque. In common with other polystyrenes, Styron 700 possesses good resistance to alkalis, salts, lower alcohols, and water.

Styron 440, which, like Styron 700, has also been developed to provide superior heat resistance, i.e., 98°C, is a high-impact grade, but the inherent properties of general-purpose polystyrene, such as chemical resistance, dimensional stability, specific gravity, and electrical properties, have largely been retained in the Styron 440 formulation, which is available in natural and in a wide range of opaque colours. Sheet extruded in this grade possesses a high gloss and a fine surface texture. Close dimensional tolerances can be maintained, making it ideally suitable for vacuum-forming.

Damp-Proofing Treatment for Buildings

A new treatment, claimed to drive out existing damp or to damp-proof materials which are already dry, is announced by the Water Repellent Division of Brearley Concrete Units Ltd., of Birmingham 19. The new treatment, designated "Stroma", is stated to be effective for use on both the horizontal or vertical surfaces of brickwork, stone, concrete, roughcast, and plaster in old and new buildings, and to be particularly successful in combating rising damp in walls, and as a damp-proof membrane on concrete floors, and under wood blocks, linoleum, and plastic tiles.

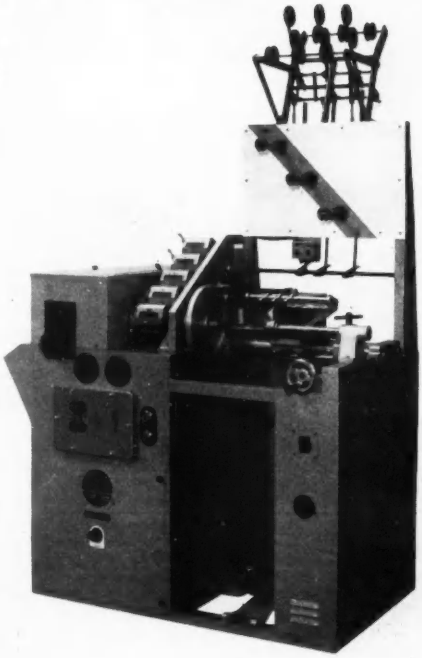
The "Stroma" solution does not contain silicones, resins, or bituminous materials, all of which merely seal or treat the surface to be treated. Actually, the solution penetrates the material to which it is applied, in some cases up to a depth of 9 in., depending on porosity, forming a damp-proof barrier. Furthermore, it cannot damage the surface and will not affect any subsequent covering such as paint, plaster, or paper. Because of its deep penetrative power, an effective life of at least twenty years is claimed.

Two types of solution are available, i.e., colourless and tinted. The colourless solution is intended for exterior surfaces and, in addition to its damp-removal and damp-prevention characteristics, not only improves the external appearance of the material treated, but also tends to keep them free from dirt or soot. The tinted solution is recommended for internal applications or where preservation of the original colour of the treated surface is not important. This solution leaves a whitish tinge which can, however, be largely removed, if desired, by brushing it with a stiff brush after drying.

Three-Coil Winding Machine With Counters

A new coil-winding machine, capable of winding simultaneously three coils up to 9 in. in diameter and up to 4 in. in width, using wires from 14 to 42 s.w.g., is announced by Westool Ltd., of St. Helen's Auckland, Co. Durham. The machine can also be provided with up to five predetermining revolution counters, and also with an "end-of-layer" stopping device to facilitate hand interleaving.

Reels up to 6 in. in diameter are mounted on the upper reel carriers, and reels up to 15 in. in diameter on the heavy reel carriers at the rear of the machine, which



70-mile over-water path employing the latest automatic diversity system in which the SHF signals are combined in the correct phase before entry into the receiver.
GANDER
CORNER BROOK
NEWFOUNDLAND
CLARENVILLE
RED ROCKS
ST. JOHN'S
CAPE NORTH
SYDNEY
0 20 40 60 80 100 MILES
0 20 40 60 80 100 120 140 160 KILOMETRES
TERMINAL
REPEATER
600-CIRCUIT CAPACITY 2-WAY TELEPHONE CHANNEL
1-WAY TELEVISION CHANNEL
2-WAY TELEPHONE & TELEVISION STANDBY CHANNEL

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S.T.C. are supplying main line microwave telephone systems to 16 countries and have already supplied systems with a capacity of over 1 million telephone circuit miles, 2000 television channel miles and an equal capacity of standby equipment.

S.T.C. are supplying a 4000 Mc/s multi-channel microwave telephone and television system to the Canadian National Railways. It will form the final link in the trans-Canadian television network. The 536-mile route between St. John's and Sydney, Nova Scotia includes a 70-mile over-water path, employing dual diversity reception, across the Cabot Strait.

Standard Telecommunications Laboratories, England, in conjunction with S.T.C. (Canada) carried out the propagation tests on the route and S.T.C. (London) in collaboration with their Canadian associates will provide technical assistance during installation.

S.T.C. are also supplying: 7000 Mc/s Microwave Links to Television Studios, Supervisory and Remote Control Equipment, Antennae, Test Equipment and Entrance Cables.

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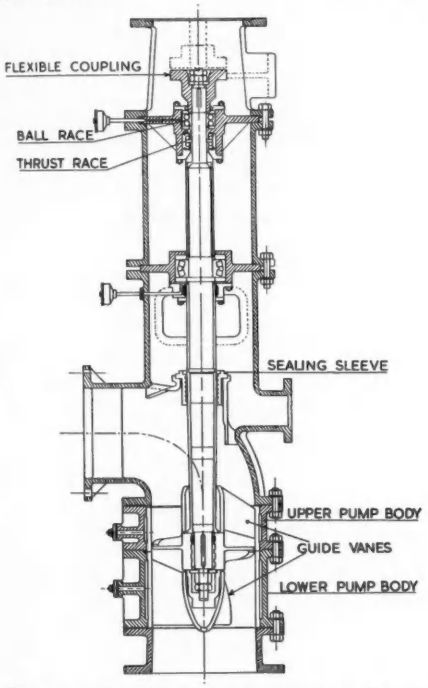
can also be used for "pack feeds". Four speed ranges are provided, i.e., 0 to 350 rpm, 0 to 750 rpm, 0 to 1500 rpm, and 0 to 2000 rpm. A pedal controls the rate of acceleration from zero to maximum on any range. The reversing mechanism used comprises two electric brakes coupled to two worm-wheels in constant mesh with two lead-screws, while an arrangement of adjustable stops and microswitches gives positive and instantaneous reversal of direction. The length of traverse can easily be adjusted, and the "turns-per-inch" setting is obtained by means of a plastic handwheel moving against a calibrated scale engraved in s.w.g. sizes or in decimals of an inch, if preferred. An electric brake is incorporated in the headstock drive, and the braking value can be adjusted by means of a knob to suit varying gauges of wire.

The machine is provided with a soldering-iron recess and soldering-iron socket outlet. If desired, a full-speed "lock-on" foot-switch can also be provided, whereby, after full speed is attained, the pedal remains locked until cutting out on the predetermining revolution counter. The machine may also be fitted with two small pilot lamps showing the instant that a change in direction of traverse has occurred, thus facilitating setting up for accurate coils.

Vertical Glandless Pumps

Designed for applications requiring the circulation of corrosive liquors, e.g., rayon spin-bath liquor in high-vacuum crystallizers and caustic soda from electrolytic cells in forced-circulation evaporators, a new series of vertical glandless pumps, designated type *H*, is announced by the Kestner Evaporator and Engineering Co. Ltd., of London, S.W.1.



These pumps, which have a high capacity (a typical example is 3300 gpm), are of the axial-flow propeller type, provided with guide vanes on both the suction and delivery sides. The shaft is in mild steel, sheathed in antimonial lead in the form of an homogeneous coating, and other sleeves in silicon iron provide anti-corrosion protection towards the bottom of the shaft. Steaming-out points, intended only to facilitate dismantling the pump during overhauls, are provided and are placed in the annular space between the pump body and the body sleeves. These are required only when it is necessary to get rid of crystal build-up between these components.

The pump has no gland or bearing in contact with the liquor being pumped, and can be arranged to operate in two ways. In one arrangement, a supply of "sealing" liquor may be fed into a chamber adjacent to the sealing sleeve and led away through a branch. Alternatively, the liquor effects its own seal when this branch is blanked off.

Dust-Collection Plant with Selective Particle Acceleration

Manufactured by the Gas Cleaning Division of Steels Engineering Installations Ltd., of Sunderland, under licence from the Termokimik Corporation, of Milan, the "SPA" dust collector belongs to the multi-cellular group of dry centrifugal plant but incorporates a special principle of particle acceleration. This principle, known as "Selective Particle Acceleration", eliminates collector wear, ensures high efficiency with low pressure drop and power consumption, and extends collection to the smaller-size particles.

Essentially, the SPA collector comprises a number of standard elements housed in a fabricated steel body with a dust-collecting hopper, the number of elements being varied to meet the volume requirements of each application. There is no secondary system to effect final separation of the finer particles and requiring a secondary booster fan, as is the case in many high-performance collectors in this class. Separation of the entrained particles is carried out in one operation within the collector elements.

Each element comprises an inner and outer member assembled coaxially. The outer member is formed in two parts, i.e., an operating zone and a cylindrical collector tube, the two being welded together. The operating zone forms a funnel with rapidly decreasing cross-sectional area, the upper end being hexagonal in section and the lower end circular, to match the cylindrical collector tube. The inner member comprises a straight length of mild-steel tubing, flanged at the top, passing centrally through the operating zone, coaxial with the collector tube and extending a little below the bottom of the operating zone. Within the annular space formed between the operating zone wall and the inner member are placed six guide vanes, these vanes being welded to the inside of the operating zone only.

Dust-laden air enters the element over its hexagonal face at low velocity. The guide vanes immediately deflect it into a helical path and, as it passes through the nozzle, it is rapidly accelerated along this path by virtue of the decreasing cross-sectional area. The air emerges from the operating zone at a velocity which is six times greater than its entry velocity, and flows approximately two-thirds of the way down the collector tube in this helical path before reversing up the central core of the vortex and leaving the element through the inner member. The separated dust flows down the walls of the open-ended collector tube and is deposited in the hopper beneath. A straightening vane, placed inside the inner member, recovers some of the swirl energy and reduces frictional losses by restoring straight flow.

The special feature of the plant is the acceleration of the air as it passes through the operating zone on its helical path. This acceleration is very rapid (the air traverses the nozzle in approximately 0·009 sec), with the result that the larger particles, by virtue of their inertia, attain lower speeds than the small particles. As the different sizes of particles are accelerated in their helical path (more or less rapidly in inverse ratio to their mass) they are acted on by increasing centrifugal force. When the centrifugal force acting on a particular particle is sufficient to overcome the viscous drag of the air in which it

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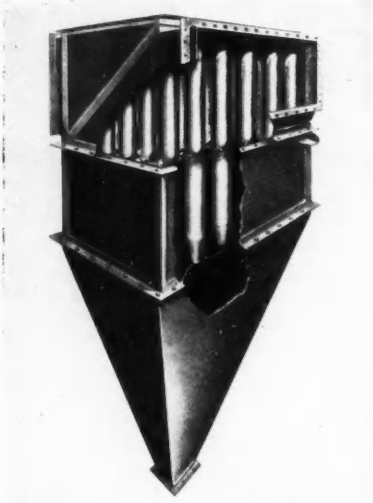
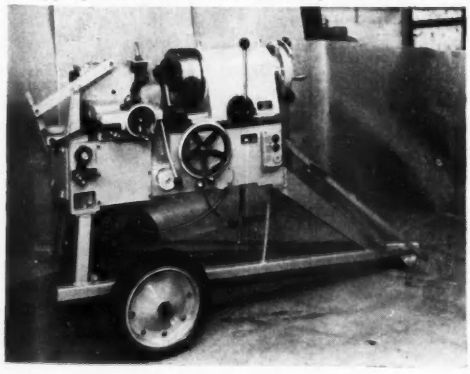


is immersed, the particle travels radially towards the wall of the operating zone to be collected.

Since the centrifugal force acting on the particle is proportional to its mass, lower velocities are required to effect separation of the larger particles. Conversely, by accelerating the dust-laden air, sufficient centrifugal force is established early in the acceleration to separate the large particles, leaving only the smaller particles to be accelerated to higher speeds to effect their separation. This principle of selective particle acceleration brings in its train selective particle collection, in which the larger the particle, the earlier and consequently the slower is it collected. In this way, the air stream is rapidly cleaned of large particles, thus permitting it to be accelerated to the higher speeds necessary to centrifuge the very small particles.

Automatic Tube-Cutting and Screwing Machine

The latest addition to the "R.G." range of tube-cutting and screwing machines made in Germany by Ruhrstahl A.G., of Brackwede, is the "R.G.-Auto", stated to be the first entirely automatic machine of its kind. The new machine, which is available from the world agents, J. C. Neville Limited, of London, S.W.14, can cut, bevel, and thread tubes from $\frac{1}{2}$ to 4 in. in diameter cleanly and without burr merely by operation of the appropriate switch. Parallel or taper threads can be



cut rapidly and efficiently to all British and foreign standards, specimen threading times being 20 sec for tubes of 1-in. diameter, 40 sec for 2-in. diameter, and 120 sec for 4-in. diameter.

No resetting of the tubing is required when changing from cutting to threading, or vice versa, and only very minor adjustments are necessary when changing from one thread to another. Furthermore, the milling hobs are of an entirely new design, ensuring exceptionally long life, while the feature of completely automatic operation eliminates any danger of overloading. The machine can be supplied with an electric drive or as a portable trolley or trailer unit powered by a petrol motor. For workshop use, a bench-fitting model is also available.

Midget Air-Cylinders

To meet the demand for a small, powerful, and compact air-cylinder, A. Schrader's Son, of Erdington, Birmingham, a division of the Scovill Manufacturing Co., have added to their range a new midget type with a double-acting cylinder of 1 in. bore. Six different lengths of stroke are available, ranging from 1 to 12 in.

These cylinders, which have a 1-in. neck mounting thread, with a lock-nut for easy assembly in any position, can be used for pressures up to 125 psi, and are specially suitable for such applications as the operation of jigs and fixtures, and transfer and special-purpose machines. Their construction is robust, ensuring long, trouble-free service under rapid and arduous working conditions. The cylinder body is of brass and incorporates solid brass end-plates of the screw-on type, with hexagonal flats for easy maintenance without special tools. Greater compactness is achieved by eliminating tie-rods. The piston rod is of ground and polished steel, and a cartridge-type bronze bearing and piston-rod seal, replaceable without dismantling, are incorporated. The cylinder is packed with molybdenum disulphide grease for extended performance without constant attention.

An Instrument for Measuring Pore-Size Distribution by Mercury Penetration

(*Concluded from page 214*)

from full vacuum to atmospheric, a specially designed filling device, and an angle indicator behind the filling device. Mercury can be drained away from the tip of the penetrometer while it is still in the inverted position, and the filling device can be rotated in front of the indicator to any desired angle. By proper manipulation, controlled pressures below atmospheric can be obtained, consisting of the sum or difference of air pressure admitted to effect filling of the penetrometer and mercury head within the penetrometer. Thus, the upper limit of the determination is readily extended to 100 μ diameter. Between 100 μ and 10 μ (the upper limit of the prototype instrument) is found the important structure of many materials, including paper and other fibrous sheets, electrodes and diaphragms, and coarse filters.

Results which may normally be expected from the hydraulic instrument described are illustrated for three materials in Fig. 3, in the form of curves showing volume of penetration of the sample *versus* pore size. Duplicate determinations were made with each material, and these are shown in the graphs by different symbolism, reproducibility being indicated by basing a single curve on the two sets of data. The samples of sintered glass were cut from opposite sides of a single filter disc. Two similar, but separately fabricated, iron pieces were used. The samples of felt were pieces cut from adjacent locations in the original material.

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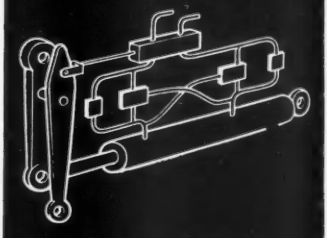

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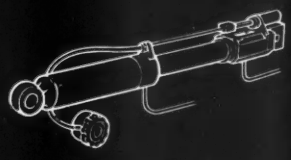

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ADDITIONAL ABSTRACTS

Numerous important abstracts which, for lack of space, cannot be published in our main editorial columns are regularly included in condensed form in this section. Subscribers may obtain photostat copies of all original articles at cost.

Experiments on Two-Stroke Engine Exhaust Ports under Steady and Unsteady Flow Conditions.

By R. S. BENSON. (From an advance copy of a paper received from *The Institution of Mechanical Engineers, London*, April 1959, 26 pages, 31 illustrations)

THE need for more power per unit weight for marine and other high-powered diesel engines has concentrated development on the supercharged two-stroke cycle engine with exhaust turbo-superchargers. The difficulties in supercharging two-stroke cycle engines with exhaust turbochargers are associated with the need to ascertain whether sufficient air would be available over a wide speed range, without the use of an external or an engine-driven pump. The power developed by an exhaust turbo-charger is dependent on the pressure and temperature of the exhaust gases at the entry to the turbine. In order to obtain maximum power there should be minimum amount of throttling and pressure loss in the exhaust system. The object of the work described in this paper was, therefore, to establish, theoretically and experimentally, data for the design of exhaust ports.

Two different theoretical approaches were used. In the first, the discharge was analysed by the method of characteristics, and it was shown that the discharge was by wave action. The second approach neglected the particle velocity in the cylinder. Comparison of the latter with the solution by characteristics showed good agreement over the main part of the discharge, so that it was possible to develop a simple design formula for the estimation of the port area.

The experimental investigation was carried out on a special machine, which simulated in all respects the exhaust-port arrangement of a two-stroke cycle engine. The machine was designed to investigate the effect of port configuration, port timing, cylinder length, engine speed, release pressure, and temperature. By suitably arranging the variables in non-dimensional groups, a wide range of engines could be simulated. The flow characteristics of the exhaust ports were examined under both steady and unsteady flow conditions, and the following conclusions were drawn:

(1) The coefficient of discharge for the exhaust ports increases with cylinder pressure and decreases with increased port area.
(2) The coefficient of discharge is lower under dynamic conditions then under steady-flow conditions.
(3) The dynamic coefficient of discharge decreases with reduction in cylinder length at release.
(4) The effect of early port opening is to reduce the blowdown time.
(5) The effect of piston movement during discharge is to reduce the effective port area required.

The Effect of Speed-Dependent Friction and Backlash on the Stability of Automatic Control Systems.

By E. A. FREEMAN. (From *Applications and Industry (A.I.E.E.), U.S.A.*, No. 40, January 1959, pp. 680–691, 18 illustrations)

IN the production of remote position control systems, there is a limit to the accuracy of the gearing connecting the motor to the load. To be practical, the gearing must possess some backlash, affecting the performance of the control system. In some cases, this may be of little importance but, as restrictions on the accuracy of control become more stringent, the effect of backlash assumes greater importance.

In the investigation described in this paper, it is assumed that linear speed-dependent friction is applied to both the motor and the load. The effect of backlash and friction on the stability of the control system is examined by means of the describing-function technique. A method of deriving the describing function is given, and it is shown that the presence of friction modifies the application of the describing function as presented by Tustin.* In particular, it is shown that, although the positional reset may be divided in the ratio of inertias, the system may still exhibit sustained oscillations, and the choice of system parameters to eliminate these oscillations is discussed. To illustrate the effect of backlash and friction quantitatively, a second-order control system with output-velocity feedback is considered. It can be shown that, if all reset is taken from the load, the system becomes unstable for all values of damping coefficient. Stabilization can be achieved either at the expense of positional error, by taking all reset from the motor, or by taking positional reset from the load and the velocity signal from the motor. In the latter case a stability limit can be predicted, agreeing closely with measurements from an electronic simulator.

* *Journal Inst. Elect. Eng.*, Pt. IIA, 1947, 143–151.

The Use of the Hot Torsion Test for Determining the Forgeability of Steel.

By G. WALLQUIST and J.-C. CARLÉN. (From *Jernkontorets Annaler, Sweden*, Vol. 143, No. 1, 1959, pp. 1–28, 21 illustrations)

MANY attempts have been made to find a simple laboratory method for determining the relative forgeability of different steels by means of tension, compression, bend, indentation, and torsion tests, as well as by special rolling and die-filling tests. Of these the torsion test appeared to be the most reliable, and it was decided that a research programme of Jernkontoret should include an investigation into this test method. This paper reports the results of the investigation.

Twelve different steels were tested, including carbon steels and low- and high-alloy steels. The number of twists to fracture, the torque, and the torsional work were studied as functions of the steel composition, the temperature of the steel, and the speed of twisting. The testpieces consisted of rods, 250 mm in length and 20 mm in diameter, which had been turned to 10 mm to give a gauge length of 100 mm. The temperature varied from about 700° to 1250°C, and the twisting speed from less than 10 rpm to about 200 rpm.

For all steels except the soft carbon steels the number of twists to fracture was found to rise with temperature up to a certain limit and then to fall off again. The maximum value is within the austenite range and differs with the steel composition. The number of twists is lowered by increased twisting speed and is strongly influenced by the steel composition. Thus, while eutectoid and slightly hypo- and hyper-eutectoid carbon steels were found to have the highest plasticity with up to 770 twists to fracture, a soft carbon steel of commercial grade would stand only about 180 twists, while some high-alloy steels, e.g., stainless and high-speed steels, withstood a rather low number of twists, in some cases with a maximum value of 20 twists.

In conformity with the results obtained in other investigations on deformation, it was found that, on transition from the alpha to the gamma state, the number of twists to fracture decreased with a corresponding rise in the torque. Within the austenite range the torque decreased rapidly with rising temperature.

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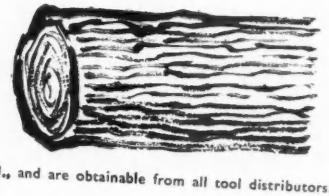

'Eclipse' hacksaw blades and other tools are made by James Neill & Co. (Sheffield) Ltd., and are obtainable from all tool distributors.

UH 27.

It is concluded from this investigation that neither the torque nor the torsional work to fracture constitutes a guide to determining forgeability. On the other hand, it appears that the number of twists to fracture can be used as an indication of plasticity and therefore as a comparison of the forgeabilities of different steels.

Inert-Plus-Nitrogen-Gas Metal-Arc Process for Welding Aluminium.

By G. ALLEN. (From *The Welding Journal*, U.S.A., Vol. 38, No. 3, March 1959, pp. 132s–141s, 9 illustrations)

WITH the object of reducing the cost of aluminium welding and to make it less dependent on the supply of inert gas, a special technique of gas-shielded metal-arc welding has been developed and is described in this paper. This technique is an inert-plus-nitrogen-gas process, utilizing 5 cu ft/hr of inert gas through the contact tube and 15 cu ft/hr of nitrogen through the regular gas nozzle of the welding gun. A short, visible welding-arc technique is necessary in multi-pass welds to prevent heavy formation of infusible aluminium nitride on top of the weld beads.

Test results show that the mechanical and electrical properties of weldments of a grade of aluminium, at least 99·45% pure and widely used as an electrical conductor, fabricated by this process are satisfactory for aluminium bus-bar welding. The nitride inclusions strengthen the weld metal in these aluminium weldments, but reduce the ductility of the weld metal slightly. The electrical resistance across these welds is approximately equal to that of an equivalent length of base bus-bar, provided that the weld-bead reinforcement is left on, as is normal in bus-bar welding. In addition, an 8-month corrosion test of welds made by this technique in aluminium of this grade with a filler of 1100 aluminium alloy showed no evidence of significant pitting in the weld metal, heat-affected zone, or parent metal. There was no evidence of the nitride films decomposing in contact with moist atmospheres.

This welding process can also be used satisfactorily on aluminium alloys with little or no magnesium, using a filler wire also with little or no magnesium, provided that high-quality welding is not the prime requisite. With high-magnesium aluminium alloys there is an exothermic reaction between the nitrogen and magnesium, so that the technique is not recommended for welding these alloys.

Vibrations of Vertical Milling Machines under Test and Working Conditions.

By S. A. TOBIAS. (From an advance copy of a paper received from *The Institution of Mechanical Engineers, London*, March 1959, 21 pages, 20 illustrations)

THE elimination of chatter arising during face-milling operations is of considerable practical importance. Chatter is undesirable from the standpoint of surface finish and machining accuracy, and is highly detrimental to the tool life of the carbide-bladed cutters extensively used in modern workshops. The dynamic behaviour of vertical milling machines is also of interest, owing to recent developments in computer-controlled contour-milling. Experience has shown that vertical milling machines of conventional design possess certain features which are undesirable from the control-engineering standpoint. It has been realized that the new exacting demands can be met only after a considerable amount of fundamental machine-tool research has been carried out, and work along these lines is already in progress in several laboratories. However, the major part of this research effort appears to be directed towards the improvement of the various machine-tool elements, i.e., slides, bearings, etc., and relatively little attention is being paid to the vibrational characteristics of the machine-tool structure and the dynamics of the cutting process, i.e., vertical milling-machine chatter.

The investigation described in this paper is concerned with an experimental investigation of the vibration of vertical milling machines under test conditions. It is shown that, in the frequency range investigated (6000 to 10,000 cps), the machine structure has five modes of vibration which respond with large amplitudes. The dynamic deflections corresponding to these are discussed, and attention is drawn to certain structural weaknesses frequently encountered in vertical milling machines.

In addition, various experiments concerned with face-milling chatter are reported, and it is shown that the severity of chatter depends on the relative position of cutter and workpiece and the depth of cut. When the depth of cut exceeds a certain minimum value, the machine chatters in definite speeds bands which are separated by chatter-free speeds. As the depth of cut is increased, the chatter-free speed bands contract. From this and the variation of the chatter frequency, it is concluded that the chatter observed is of the regenerative type, similar to that arising in the case of drilling and other machining processes.

Finally, a theoretical interpretation of the experimental results is given. Chatter behaviour is discussed with the aid of a three-dimensional chart, for the construction of which the required constants were extracted from the experimental results obtained. It was found that correspondence between theory and experiments was satisfactory.

Overcoming the Problem of Stress-Corrosion Cracking in Aluminium-Bronze.

By J. F. KLEMENT, R. E. MAERSCH, and P. A. TULLY. (From *Metal Progress, U.S.A.*, Vol. 75, No. 2, February, 1959, pp. 82–86, 6 illustrations)

ALUMINIUM-BRONZES, with their combined strength, formability, weldability, and corrosion resistance, have been increasingly used in the process industry as sheet and plates, condenser tubes, pipes, and bolts. However, an unexpected trouble has interfered with their wider acceptance, i.e., the alloys have cracked from stress-corrosion in steam. Such spontaneous failures in stressed brass and bronze alloys under mild corrosive attack have caused more unpredictable difficulties than any of the more common types of corrosion. Only too often, laboratory tests involving complete, alternate, or line immersion have failed to indicate danger of premature failure.

Steam, often carrying a minor amount of acids, alkalis, or various salts, is basically responsible for such failures, these vaporous atmospheres causing trouble when residual or applied stresses are present in a pressure vessel or an acid distillation unit operating at temperatures between 180 and 500°F. In fact, a theoretical evaluation of the stress-corrosion problem indicates that the cause of the intergranular cracking is related to the segregation of the aluminium in the alpha grain boundaries. Here, the aluminium is attacked and oxidized by steam, while the stress causes continual rupture of any protective oxide film which forms, resulting in crack propagation and eventual failure.

Prevention of such attack must involve the elimination of equilibrium grain-boundary segregation of aluminium atoms. Experiments on processing have proved that this cannot be done through any modification of melting, casting, rolling, or heat-treating techniques, although methods have been found which resisted failure for a longer time.

The addition of 0·35% tin to the aluminium-bronze alloy has, however, produced a modified alloy which has been found to have a very high (if not complete) resistance to intergranular stress-corrosion cracking. The addition of this amount of tin has no noticeable effect on any of the mechanical or physical properties of the alloy, nor on its forming or welding characteristics. An extensive programme of testing in both the laboratory and in pilot field applications has failed to produce failures in this modified alloy, while the same tests on the unmodified material have invariably resulted in stress-corrosion failures in a few days or weeks.

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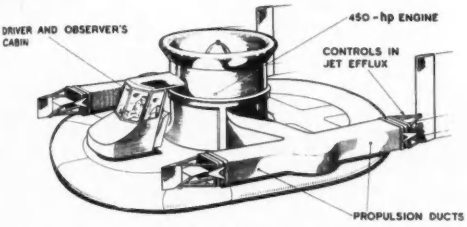
EXPERIMENTAL " HOVERCRAFT "

As a result of Cockerell's experiments in 1953, showing the possibility of supporting a craft on a cushion of air and of propelling and controlling it horizontally by bleeding off some of the air through suitable nozzles, the National Research Corporation, through its subsidiary (Hovercraft Development Limited), placed a contract with Saunders-Roe Limited, of Cowes, to undertake the research, design, and development of a man-carrying experimental saucer-shaped " hovercraft ", suitable for use over water. Designated the SR N1, this hovercraft is about 30 ft in length and 24 ft in width, and is powered by an Alvis Leonides 450-hp engine, which drives a ducted fan to provide the air supply for lift and propulsion. The SR N1, which will have a crew of two, is nearing completion and its first tethered trials will take place in June, after which free trials will be carried out on the Solent.

The hovercraft is not an aircraft, as it does not rely on wings and forward speed for lift; neither is it a ship, inasmuch as it operates clear of the water, i.e., between 3 and 7 ft above the surface. In fact, it may be said to fill the gap between an aircraft flying at high speed with a comparatively small payload and a large-capacity ship travelling at lower speeds. In this connection, it is envisaged that hovercraft, weighing thousands of tons and capable of speeds of about 100 knots, will eventually be possible.



In the experimental SR N1, hand-carved wooden fan blades, designed and constructed by The Airscrew Company and Jicwood Limited, of Weybridge, Surrey are used to provide the lifting force and bleed-off air for propulsion. The four blades of the fan are constructed from laminations of mahogany, bonded with a waterproof synthetic resin and covered with a special plastic material. The leading edges of the blades are protected by a metal sheath. Accurate balance of the impeller is obtained by control of the shaped dimensions of the blades. In addition, pre-rotational vanes are provided, constructed of resin-bonded birch veneers, 0·04 in. in thickness, with the grain direction arranged to give optimum strength characteristics. These vanes are built into a rigid central blanking carrying the nose fairing. The pre-rotational vanes and the blanking assembly are dowelled and are bonded at the blade tips to a section of ducting, also made of wood. The duct is double-skinned and mounted on plywood rings, and the entire assembly is finished with an aluminium bituminous paint.

RADIATION-TYPE STERILIZER

A new lost-cost, high-voltage electron accelerator, the " Dynamitron ", is now being offered by the Wilmot Castle Company, of Rochester, N.Y., for sterilizing applications. The device is capable of converting high-frequency a.c. power to high-voltage d.c. power, with a high power-transfer efficiency, using relatively simple and compact equipment, electrical charge being electronically pumped from earth to a high potential without the mechanical limitations of electrostatic generators. Thus, the " Dynamitron " converts large amounts of electrical power into kinetic energy in the form of a beam of high-velocity atomic particles which can be used to produce sterilization effects on a massive scale.

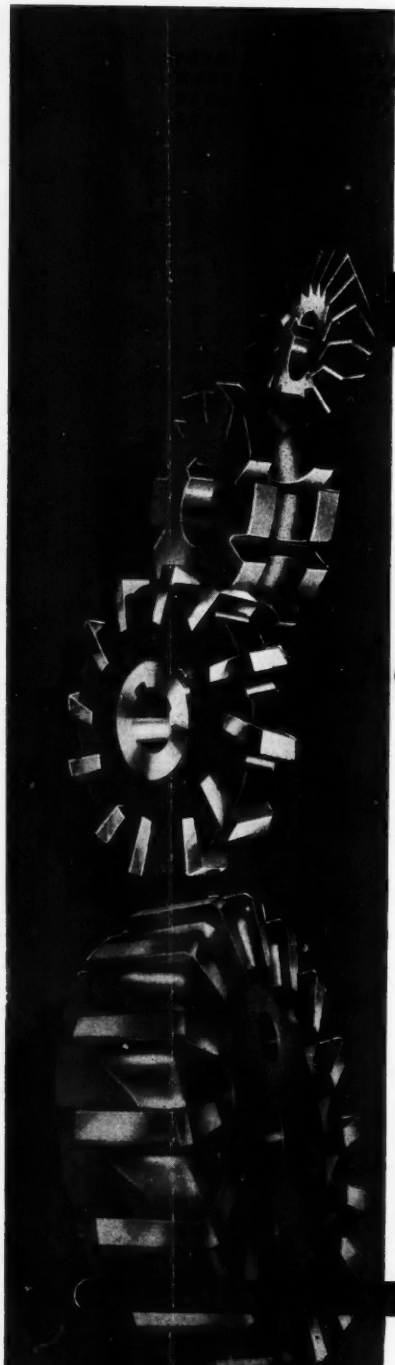
The unit, which is available in two sizes, i.e., 1·5 MeV with 15 kW of beam current, and 3 MeV with 30 kW of beam current, is essentially a cascaded rectifier system in which all rectifiers are driven in parallel from a high-frequency oscillator, the resonant tank circuit of the oscillator being mounted concentrically inside the pressure vessel. The tuning capacitance of the resonant circuit capacitively couples the R.F. potential to the rectifier terminals, which are in the form of semicircular corona rings that suppress corona discharge and act as the plates of the gas dielectric discharge. Direct-current voltage components are added successively up the rectifier column until full voltage is obtained on the high-voltage terminal. The charge is then accelerated down an evacuated beam tube and out through a thin exit port at the bottom of the unit. For sterilizing purposes, beam penetrating power is estimated at 0·33 cm/MeV for a material of unit density, and this penetration can be increased to 0·81 cm/MeV by splitting the beam and irradiating both sides of a product.

PROXIMITY SWITCH WITH CONTINUOUSLY VARIABLE DIFFERENTIAL CONTROL

Stated to be the first of its kind to incorporate continuously variable differential control, the new " Leveltron " capacitance-operated industrial controller announced by Thomas Industrial Automation Limited, of Altrincham, Cheshire, makes it possible to choose from a wide differential range between 1 and 40 pF by adjustment of two simple controls. The first control sets the control point of the relay, and the second then varies the reset point without affecting the control-point setting, fixing the differential as required. The instrument is therefore eminently suitable for covering the majority of industrial applications for free-flowing solids and liquids, as well as for monitoring sight-glass or manometer levels, while its variable-differential feature provides great flexibility and widens its scope by permitting adjustment to obtain optimum conditions for each application and subsequent adjustment to changing plant requirements. In addition, it enables one instrument to be used in cases where previously two instruments of the fixed-differential type would in many cases be necessary.

The relay current is triggered to provide a snap action of the relay and to eliminate chatter or creep. Reliability is also improved by the conservative rating of all components, and the design of circuits to fail-safe, as far as is possible in practice. Control-point drift, under conditions of steady supply voltage and temperature, is less than 1 pF over a period of three months, less then ± 1 pF for variations in supply voltage between $+10\%$ and -15%, and less than 1 pF for ambient temperature changes between 0 and 40°C. The corresponding values for differential drift are about 0·5 pF. Variations resulting from humidity are negligible.

Three basic instruments are available, i.e., a general-purpose, a heavy industrial, and a remote-control model, each offering a choice of supply of 110, 240, or 440 V, a.c., 40 to 60 cps. Measurements can be taken at a distance up to 60 yards from the point of detection, and a new transmission link system minimizes the increased non-working capacitance of the increased cable length. As the measuring unit is located in the main control box, and not in the



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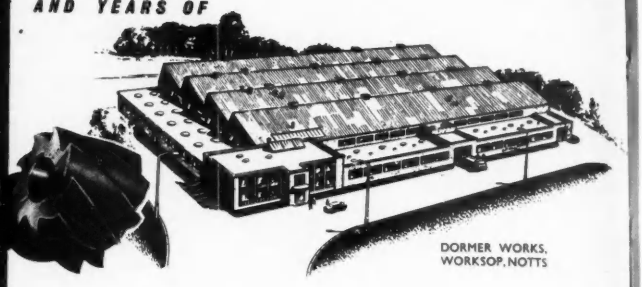

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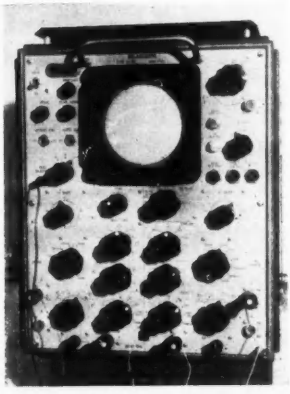
simple selector provides for high- or low-level operation, and a wide range of electrodes is available to meet practically all industrial applications, including a new special-duty electrode for use in the level detection of all types of powders, granular materials, etc. and also for liquids of fairly high viscosity.

INFINITE-PERSISTENCE OSCILLOSCOPE

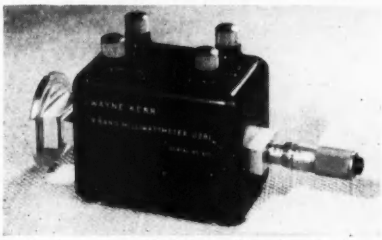
Utilizing a " Memotron " storage cathode-ray tube which gives an infinite trace persistence, though the trace can be erased immediately when required, the new infinite-persistence oscilloscope, type QD.910, announced by the Solartron Electronic Group, Ltd., of Thames Ditton, Surrey, makes it possible to freeze non-recurrent waveforms and other types of curves on the screen for as long as desired. The instrument is a dual-channel type and completely supersedes ballistic galvanometers, pen recorders, or smoked cylinders for the accurate visual evaluation of transient or non-repetitive phenomena. Comprehensive facilities, similar to those found in an advanced general-purpose oscilloscope, are provided, so that it can be used in all cases where continuous photographic recording from an oscilloscope was formerly necessary.



The " Memotron " tube contains an orthodox writing gun and deflector-plate assembly, with an acceleration potential of 3 kV, and a medium-persistence viewing screen, with a potential of +3 kV, applied to it. Behind the viewing screen are two fine wire meshes, i.e., the collector and storage meshes. The collector mesh, which is adjacent to the viewing screen, has a coating on the far side of a dielectric material with a secondary-emission coefficient, and is normally at zero potential. The collector mesh is set at +160 V. A second gun, the flood gun, is mounted to the side of the deflector plates and floods the screen of the tube with slow electrons. When the writing gun is cut off, flood electrons leak through the storage mesh and are attracted to the viewing screen, where they produce a dull uniform illumination. When the writing gun is turned on and deflector voltages are applied to the plates of the tube, the fast-moving electrons from the gun strike the storage mesh and produce secondary electrons from the dielectric coating. The area thus written upon loses more secondary electrons than it gains in primary electrons, making positive charges which attract flood electrons, which in turn pass through the mesh and are attracted to the highly positive viewing screen, reproducing on it the pattern written on the mesh. The flood gun maintains the positive charge on the storage mesh indefinitely. Once a given area has risen above a certain potential level, it accelerates the flood electrons sufficiently to release further secondary electrons, and thus its potential continues to rise until it approaches that of the collector mesh, at which potential it stabilizes, so that the positive charge pattern is maintained. To erase the picture, the potential of the collector mesh is lowered for a short interval; secondary electrons then fall back onto the collector mesh and cancel the positive charges.

X-BAND MICROWAVE MILLIWATTMETER

The X-band microwave milliwattmeter, type U-281, introduced by the Wayne Kerr Corporation, of Philadelphia, Pa., is a portable and extremely accurate resistive film bolometer wattmeter, capable of measuring power in a range between 1 and 100 mW with an accuracy of $\pm 3\%$ over a frequency band of 8·4 to 10·2 kMcs.



Terminals are provided for calibrating the instrument against d.c. power, and micrometer adjustment permits a short-circuiting termination to be set for a voltage standing-wave ratio near unity at any frequency within the specified range. A chart, relating the frequency of operation to the required micrometer reading, is supplied. The input connection, waveguide size $1 \times \frac{1}{2}$ in., is fitted with standard flanges.

Basically, the wattmeter consists of a thin resistive film which is mounted symmetrically in the transverse plane of the waveguide. The rise in temperature of this film caused by absorption of incident microwave radiation is used to measure the input power. The temperature change is detected by a thermocouple junction mounted on the film, which can be connected to a sensitive galvanometer or a d.c. amplifier.

PEAK ACCELEROMETER FOR SHOCK-TESTING PACKAGES

Intended to meet the demand for a high-quality, but relatively inexpensive, portable electronic instrument capable of measuring shock inside packages and the cushioning properties of packaging materials, a new peak accelerometer introduced by Ferranti Limited, of Hollinwood, Manchester, enables manufacturers of electrical, electronic, or mechanical equipment, ranging from watches to large radar units, to build up valuable sets of statistics on the ability of products to withstand specific shock or vibration conditions, by measuring peak *g* values under such conditions directly and accurately.

The instrument comprises two main units, i.e., a probe for fitting on the sample under test and an indicator unit. The indicator unit incorporates a cathode follower, an a.c. amplifier, a low-pass filter with a cut-off frequency of 675 cps, an output socket for connecting a cathode-ray oscilloscope, and a double-scale, flush-mounted indicator

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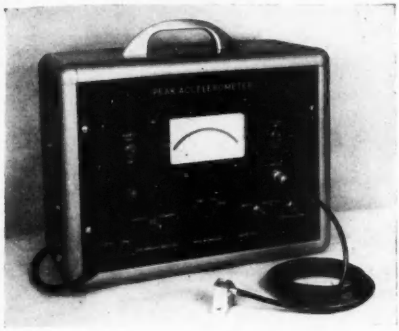
with a 3½-in. dial, giving four ranges from 0 to 25 *g*, 0 to 100 *g*, 0 to 250 *g*, and 0 to 1000 *g*. Manipulation of a switch enables vibration readings from 8 to 750 cps to be obtained. A special negative feedback technique used within the electrical system ensures that both short- and long-term reading repeatability is of a high order.



The acceleration-sensitive element or probe consists of a barium titanate crystal accelerometer fitted in a metal housing, with an output lead of screened cable, nominally 12 ft long, for plugging into the indicator unit, though the instrument, which is electronically calibrated, can also be supplied with a 60-ft length of special low-capacity coaxial cable, if required. The probe can either be attached directly to a rigid member of the sample under test or to the inner cargo container (for package testing).

In operation, the probe is attached to any rigid member of the equipment in such a manner that the probe drops on one plane onto the packaging material, which is sufficiently thick to prevent " bottoming ", i.e., full compression of the material. After obtaining a reading, which will be retained within 2% for 30 sec, even though the actual shock pulse may be as short in duration as 0·001 sec, the equipment is examined for visible and functional damage, and the probe is then connected to another plane of the sample under test. The drop test can then be repeated at different heights.

INDUSTRIAL OIL BURNERS

A new range of industrial oil burners of the proportioning low-pressure-air type, suitable for industrial furnaces and boilers, is being produced by Swinney Brothers Ltd., of Morpeth. With these burners, designated " Moduflame ", control is effected by movement of one lever, either manually or automatically, and the air/fuel ratio is maintained constant throughout the operating range. The output of each burner can be varied through a turn-down range of about 4½ to 1.

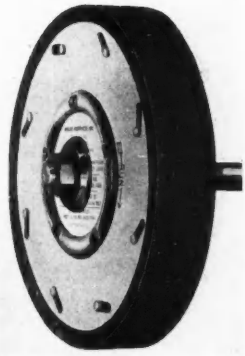
When applied to an industrial furnace, e.g., a forging furnace, all the air for combustion, except for a small amount induced around the burner nose, is normally passed through the burner. This air is supplied by a fan at pressures of between 20 and 30 in. w.g., while the oil pressure required is of the order of 10 psi. These burners are suitable for all grades of liquid fuel and are capable of easy lighting, even in a cold combustion chamber. Maximum burner outputs, with all the combustion air passed through the burner, range from approximately 6 to 40 gph.

For boiler firing, the burners may be used as above, or alternatively in conjunction with an air register, in which case the burner outputs are increased by about 200%, making the maximum outputs of the range from approximately 18 to 120 gph. When used with an air register, control of air and oil is again by means of a single lever. For automatic operation a wide variety of control schemes is available.

A unique feature of the " Moduflame " burner design is that, when using heavy fuel oils which require preheating before burning, the hot oil can be circulated through part of the burner body during non-firing periods. Thus, when light-up is required, oil at the correct burning temperature is immediately available, resulting in trouble-free ignition. Other features are that the air/fuel ratio can be varied while the burner is in operation, and that provision can be made to enable the burners to accept oil at different supply pressures without changing any part.

AUTOMATICALLY SELF-BALANCING AND EXPANDING ABRASIVE WHEEL

A new type of abrasive wheel, automatically self-balancing and expanding, and designed for faster and cooler general-purpose grinding, polishing, and deburring, has recently been developed by Miller Products, Inc., of North Chicago, Ill. The new wheel, which is made of neoprene and can be operated at a speed of 3450 rpm, accommodates an abrasive belt of 1½ in. width and 21 in. circumference.



The wheel is retained between, but is not bonded to, side flanges. Eight pins, equally spaced in a circle near the rim of the wheel, extend through the rubber and into diagonal slots in the flange plate on each side. Because the pins are free to move in the slots, the wheel is free to adjust itself in operation and to maintain perfect dynamic balance under all conditions. Since the wheel is retained by these pins and is not attached to a hub, its edge remains flat, instead of being distorted by uncontrolled centrifugal force. The pins also make the wheel explosion-proof. Moreover, belts will not slip under the heaviest work loads or during corner grinding, because of the uniform expansion of the rubber as a result of centrifugal force.

HIGH-SPEED PHOTOPRINTING MACHINE

The outstanding feature of the new " Zephyr " high-speed photoprinter announced by the NIG Manufacturing Co. Ltd., of London, W.C.1, is the use of a cyclone wind-tunnel developing principle, which makes it possible

Another Carter Hydraulic Variable Speed Drive

Carter Hydraulic Variable Speed Drive to Hopper Feeder, built by Richard Sutcliffe Ltd.

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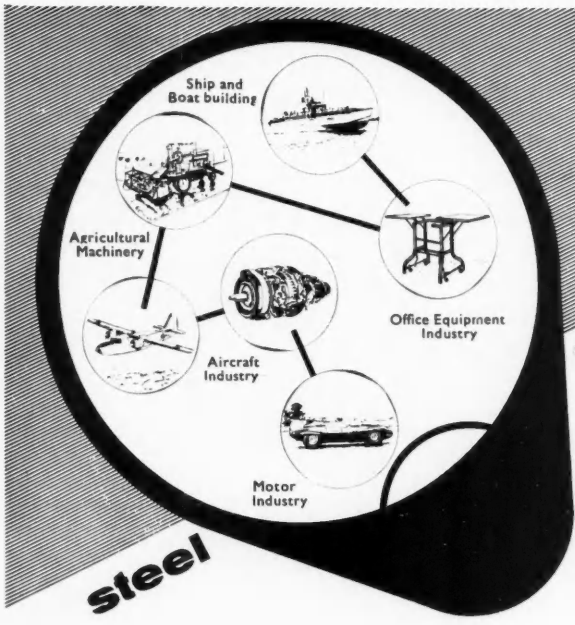

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REYNOLDS STEEL TUBING

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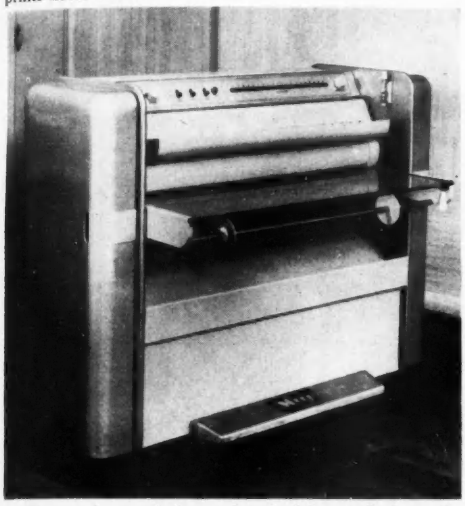
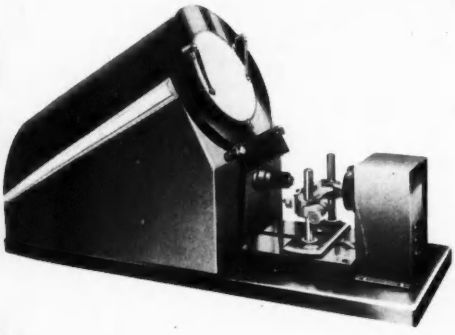
to produce a clear print in about 6 seconds. Furthermore, the machine, believed to be the fastest and most efficient of its kind in Europe to day, guarantees 100% surface development of prints at high speed and ensures that the prints never stick.



The cyclone wind-tunnel principle applied to the machine causes vaporized ammonia to be blown under pressure at a high speed by twin separately motorized fans directly onto the entirely unobstructed surface of the print, eliminating in this way perforated metal-plate or roller-tank ammonia systems, which tend to give imperfect penetration and hence cannot normally produce clear prints at high speeds. In the "Zephyr", printing and developing are synchronized, the maximum speed being 40 fpm and the maximum printing width 44 in. Illumination is provided by a 3000-W quartz tube, and cooling facilities are incorporated, together with thermostatic heat control. The printing section consists of a revolving glass cylinder, 6 in. in diameter, and the developing section is constructed throughout of stainless steel. Ammonia feed is via an automatic perspex diaphragm pump.

PORTABLE OPTICAL-GAUGING PROJECTOR

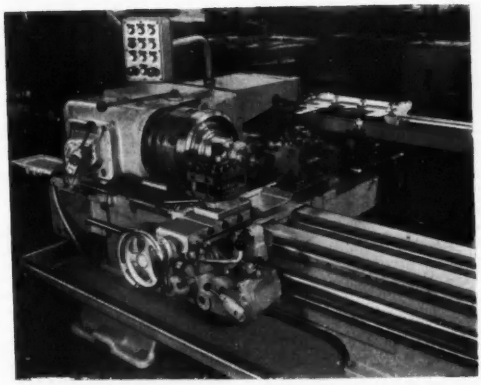
The latest standard projector in the "Shadomaster" range produced by Watson, Manasty & Co. Ltd., of Kingston-on-Thames, Surrey, is the "Minor 60"—a portable cabinet unit of extremely low cost but high precision, which can be used in either the vertical or horizontal position. Magnifications of ×10 and ×25 can be obtained with interchangeable lenses, and a full range of accessories is available. Fitted with precision lenses, a worked mirror, 1 in. in thickness, and a special collimation system, the instrument can be used for applications requiring the highest standards of optical gauging.



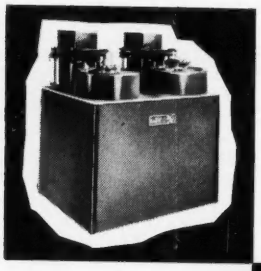
For use in the horizontal position, as illustrated, the projector incorporates a convenient workholding fixture. When the projector is used in the vertical position, a flat table is provided, held horizontally in the vice of either the workholding fixture or the co-ordinate work-stage. Into this table is fitted a glass insert, on which workpieces may be laid for inspection. The diameter of the screen, which is supplied complete with chart rest and two chart clips, is 6 in. The projector is only 28 in. in length in the horizontal position and can be carried comfortably in one hand. In the vertical position, it can be stood on a bench or fixed to a wall. One of its chief applications is the inspection of thread forms, for which the full range of "Shadoform" thread charts can be used, including Whitworth, B.A., unified, and metric. It is also eminently suitable for the inspection of small component parts, such as pressings.

TWO-DIMENSIONAL CARRIAGE TRACER FOR TURRET LATHES

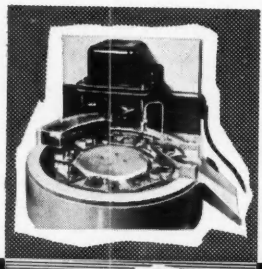
A new type of hydraulically controlled two-dimensional carriage tracer for turret lathes, with four fully automatically controlled tracing cycles, has been developed by the Jones & Lamson Company, of Springfield, Vermont. The machine can trace through 180 deg. of tool travel while turning is in progress, with the feed either inwards towards the headstock or away from the headstock. It can also trace through 180 deg. of tool travel during facing operations, with the feed either towards or away from the spindle centre-line. Roughing and finishing tracing tools can be used from an indexing square turret. The unit can also be used as a taper attachment and, with a suitable threading device, can produce tapered threads.

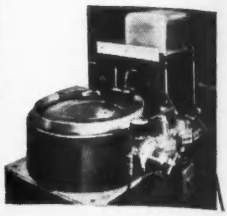


Complete size control for diameter is accomplished with a conventional graduated handwheel for either tracing or mechanical operations. As the tracer is mounted on the rear of the cross-slide carriage, it does not interfere with the normal operation of a square or hexagon turret, or with tooling positioned at the rear of the cross-slide. Templates and stylus are always in view of the operator and are free from chips and coolant. Feed limits are from $\frac{1}{2}$ to 18 ipm. If desired, feed can be changed by a single control, even during machining. The turning capacity of the tracer is the same as the mechanical capacity of the machine in 20-in. increments, while the facing capacity, in either turning or facing cycles, is up to 6-in. radius change.

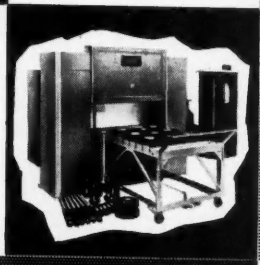


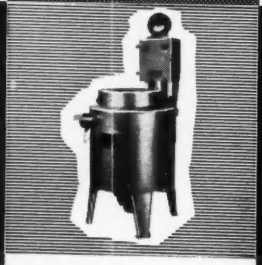
INDUCTION HEATING EQUIPMENT

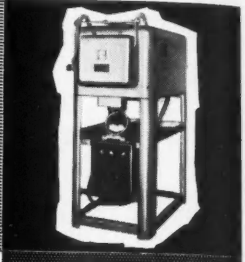


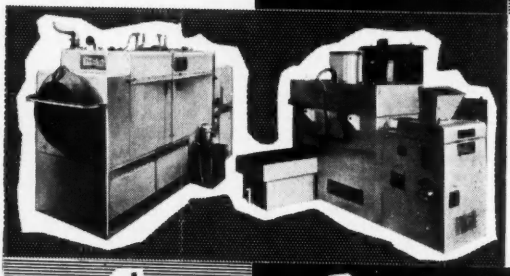


GENERAL PURPOSE FURNACES

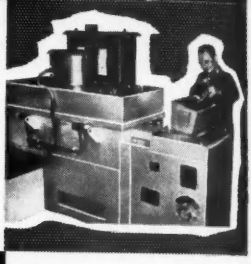


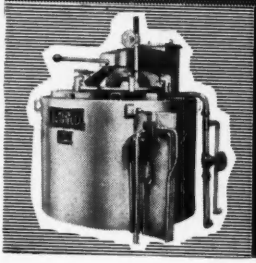


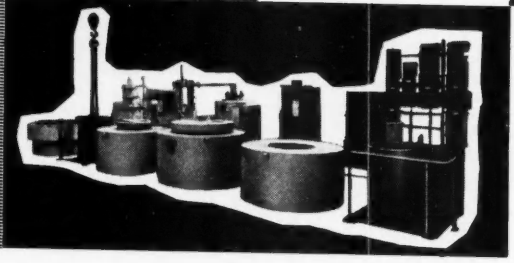




CONTINUOUS CARBO-NITRIDING FURNACES







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NEWS OF THE MONTH

PERSONAL

Mr. C. L. Champion, B.Sc., A.C.G.I., M.I.C.E., M.I.Mech.E., A.M.I.E.E., has been appointed chief mechanical and electrical engineer of the War Office Directorate General of Works.

The Westinghouse Brake and Signal Company Limited announce that **Mr. G. W. Dunkley, O.B.E.,** has been appointed a director of the company.

Mr. R. D. Hamer, F.I.M., F.R.I.C., a vice-president of the Institute of Metals, has been appointed chief executive officer of Aluminium Laboratories Limited, and will be responsible for the company's international sales in Europe, the Middle East, and North Africa, with headquarters in Zürich.

Imperial Chemical Industries Limited announce the retirement of **Sir Ewart Smith, F.R.S.,** from the board of the company. Sir Ewart has agreed to become chairman of a new council, set up to assist with the application of modern industrial techniques in the National Health Service.

Mr. L. Bailey has been appointed a director of United Steel Structural Company Limited, of Scunthorpe, a subsidiary of The United Steel Companies Limited.

Mr. S. W. Pearson has been appointed general manager of John Lumb & Company, the Castleford subsidiary of United Glass Limited.

Mr. P. M. Furse, M.A., A.C.A., has been appointed joint managing director of Furse Wholesale Limited, of Nottingham.

Mr. D. C. Gunn, B.Sc. (Eng.), M.Sc., A.I.Mech.E., M.Inst.F., has been appointed chief engineer of Cochran & Co., Annan, Ltd.

Fawcett Preston & Company Limited announce the appointment of **Mr. C. Smith** as contracts manager of the electrical division and of **Mr. A. J. Taylor** as sales office manager.

Mr. R. C. Stevens, A.C.W.A., has been appointed assistant sales manager of Clarkson (Engineers) Limited, of Nuneaton.

Mr. K. L. Coombs has been appointed divisional manager of Webb Conveyors and Automation Limited, one of the companies in the Elliott-Automation group.

Following the retirement of **Mr. W. Wehtje, Mr. M. Wallenberg** has been appointed chairman of Atlas Copco. **Mr. N. V. von Steyern,** Chief Marshal of the Swedish Royal Court, has been appointed deputy chairman of the company, and **Mr. M. Wallenberg Jr.** a member of the board.

Dr. D. F. Denny has been appointed chief technical executive of Pratt Precision Hydraulics Limited, a subsidiary of F. Pratt & Co. Limited, of Halifax.

At the 44th annual meeting of the National Federation of Vehicle Traders, **Mr. B. G. Bonnalack, M.C., T.D., M.A.,** has been elected president for the coming year.

The Right Honourable Earl of Halsbury, F.R.I.C., F.Inst.P., has joined the board of Head Wrightson Processes Limited.

Mr. E. L. Ashley, manager of the Banbury Works for over twenty-five years, has been appointed a director of the Northern Aluminium Company Limited.

Mr. V. Brenner has been elected president of the Engineering Centre at Birmingham for a fourth year of service. **Mr. C. J. Grazebrook,** vice-president, and **Mr. A. G. Banks,** treasurer, have also been re-elected.

The Du Pont Company (United Kingdom) Limited announce that they have appointed **Mr. W. P. Fletcher** as manager of their newly constructed Elastomers Research Laboratory at Hemel Hempstead.

Following the acquisition of Avo Limited by the Metal Industries Group, **Sir Charles Westlake,** chairman of Metal Industries, has been elected chairman of Avo Limited; **Mr. H. O. Houchen,** managing director of Brookhirst Igranic Limited, and **Mr. John Black,** a director of Metal Industries, have joined the board of Avo Limited. **Mr. J. H. Rawlings,** managing director of Avo Limited, has been elected deputy chairman, while **Mr. F. H. Padfield, Mr. H. S. Macadie,** and **Mr. S. R. Wilkins** remain on the board of Avo Limited.

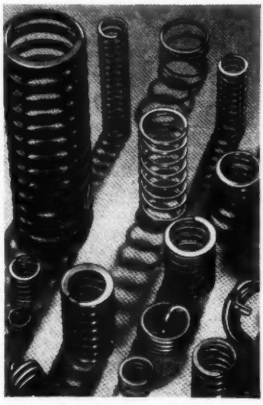
Mr. S. L. Potter has been appointed sales manager of Dunlop's agricultural and industrial division at Fort Dunlop.

Mr. F. H. Poole has been appointed joint managing director of Eva Brothers Limited, of Manchester.

Mr. C. H. Noton, M.Sc., Ph.D., F.Inst.F., M.S.M.A., has been appointed commercial manager of Semiconductors Limited, of Cheney Manor, Swindon.

Mr. W. E. Prior has been elected chairman and **Mr. J. W. Mann** deputy chairman of the British Mechanical Rubber Manufacturers' Association.

It is announced that **Major-General Sir Francis De Guingand** and **Mr. E. L. Burton** have been appointed directors of Tube Investments Ltd. Mr. Burton will continue to be secretary of the company.



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Several of these machines are already in production

Mr. C. J. Palmer has been appointed managing director of U.S. Rubber International (Great Britain) Limited in succession to **Mr. R. D. Hunt,** who has become deputy managing director of The North British Rubber Company, of Edinburgh and Dumfries.

George Ellison Limited announce that **Mr. H. Hanks,** former general manager, has been elected to the board of directors of Alfred Ellison Limited, of West Bromwich. He is succeeded by **Mr. E. A. Skinner,** former assistant general manager.

Mr. R. G. Soothill has been appointed chairman of Turner and Newall Ltd., in succession to the late **Sir Walker Shepherd,** while **Mr. R. M. Bateman** has been appointed deputy chairman.

BUSINESS NOTES

The Simms Motor & Electronics Corporation Limited announce that they have acquired the whole of the issued share capital of **Aircraft Steel Structures Limited,** of Western Avenue, Middlesex.

F. Perkins Limited announce that a new subsidiary company, named **Perkins Engines Limited,** has been formed to handle sales and servicing of their agricultural, marine, and industrial engines throughout the world. The managing director of the new company is Mr. T. H. R. Perkins, a director of F. Perkins Limited, and other directors of the subsidiary are Mr. M. I. Prichard, managing director, and Mr. W. N. Collins, a director of the parent company.

The Ransome & Marles Bearing Company Limited have moved their London office to Cranmer House, 39 Brixton Road, London, S.W.9 (Tel: RELiance 6771).

The Firth Cleveland Group of Companies have acquired the **Sheffield Wire Rope Company Limited,** of Darnall, Sheffield. Mr. C. W. Hayward, chairman of Firth Cleveland Limited, has been appointed chairman, and Mr. E. S. Mead, Mr. R. S. H. Shepard, Mr. G. F. Chambers, Mr. S. K. Wheatley, Mr. H. V. W. Buckler, and Mr. B. Allen have been appointed directors of the new subsidiary.

The Electric Motor Division of **Newman Industries Limited** have opened a new branch office at 59 Grey Street, Newcastle-upon-Tyne 1 (Tel: Newcastle 2-3970), headed by Mr. R. Martindale, the new area manager.

Weldcraft Limited, who recently became part of the **G. D. Peters Group of Companies,** have moved to Windsor Works, Slough, Bucks.

Elliott-Automation Limited announce that they have formed a new subsidiary company, **The Swartwout Company Limited,** to manufacture and sell the electronic control systems for the process, heating, and ventilating industries and for power-station instrumentation, developed by The Swartwout Company, of Cleveland, Ohio.

I.C.T. Ltd. announce the formation of **I.C.T. G.m.b.H.,** a subsidiary company with headquarters in Dusseldorf. I.C.T. G.m.b.H. will take over the existing business in Western Germany of Powers-Samas Accounting Machines (Sales) Ltd., which has hitherto been conducted through a branch office in Dusseldorf.

Metal Containers Ltd., of 17 Waterloo Place, Pall Mall, London, S.W.1, have appointed as their sole northern agents, covering Lancashire, Yorkshire, and Scotland, **Turner & Brown Limited,** of Davenport Works, Bolton, for their range of " Valethene " moulded polythene tanks up to 250 gal capacity.

The Sheffield branch of **Communication Systems Ltd.** has moved into new premises at 27 Collegiate Crescent, Sheffield. The manager of the branch is Mr. J. L. Campbell.

The Solartron Electronic Group, Ltd. have concluded with the **Svenska Flygmotor Aktiebolaget,** of Sweden, a manufacturing and marketing agreement of world-wide coverage (except Scandinavia) for a new " Vibrating-Cylinder " pressure transducer. Production has already begun in Britain and the transducer has Ministry of Supply approval for incorporation into missiles and other equipment.

Yale & Towne Manufacturing Company have acquired the business of E. Tonks & Sons Ltd., of Willenhall, makers of the " ETAS " range of locks.

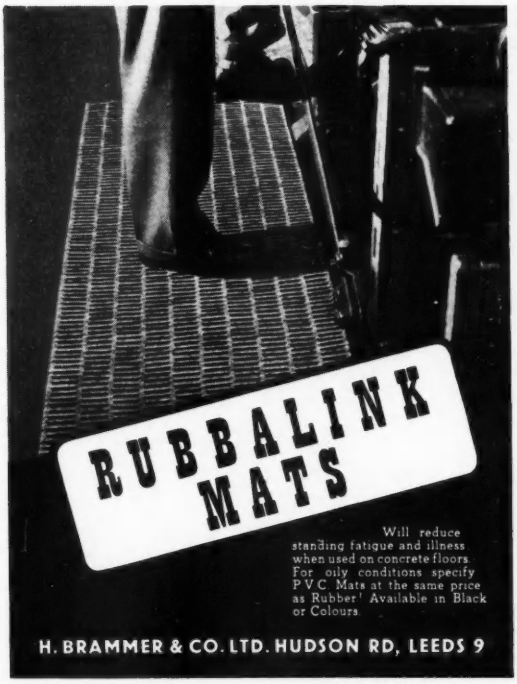
Simon-Carves Limited and **Bruce Peebles & Co. Limited,** of Edinburgh, announce the signing of an agreement for the joint design and supply of electronic-pneumatic and electronic-hydraulic control and interlocking equipment for mine car-handling and skip-winding plant and other mining applications.

EXHIBITIONS AND CONFERENCES

Lord Halsbury, president of the Institution of Production Engineers, will open a conference of engineers and others concerned, in connection with the application of standards in industry. The conference—the fifth of its kind—will be held on June 4, 1959, at the Connaught Rooms, London.

Dowding & Doll Ltd., the sole U.K. distributors for Swiss Rigid hydro-copying milling and die-sinking machines, are staging a series of special demonstrations of these machines at Elmdon Airport, Birmingham, from June 1 to 6, 1959, between 9 a.m. and 7 p.m.

The Merseyside and North Wales Electricity Board is organizing an exhibition dealing with surface heating by electricity at the Board's Industrial Development Centre, 83 Paradise Street, Liverpool, from May 20 to 29, 1959, in conjunction with Isopad Limited, and other firms.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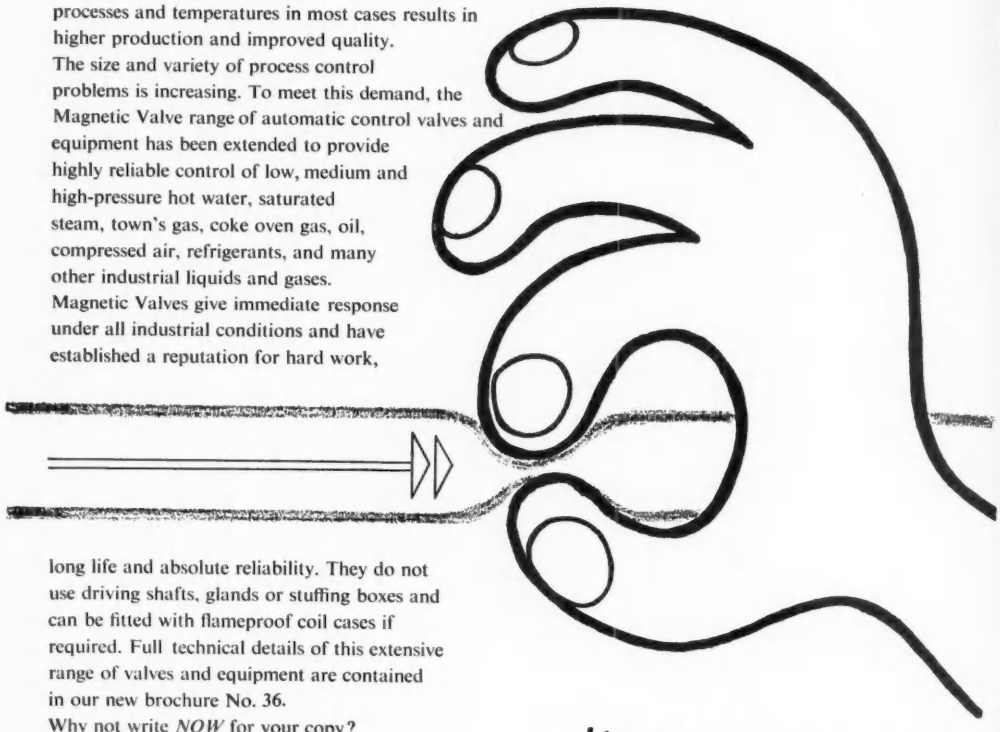

long life and absolute reliability. They do not use driving shafts, glands or stuffing boxes and can be fitted with flameproof coil cases if required. Full technical details of this extensive range of valves and equipment are contained in our new brochure No. 36.
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MV.3

Britain plans to put on the most striking demonstration of the major advances in British science, technology, and engineering, ever to have been staged in the New World, when the British Exhibition opens on June 10, 1960, at the Coliseum Building in New York. The exhibition, which will last for two weeks, is being organized by the Federation of British Industries through its exhibition company, British Overseas Fairs Limited, and has the full backing of H.M. Government, the Dollar Exports Council, and the British-American Chamber of Commerce in New York.

A private exhibition is being held by the Mond Nickel Company at Cutlers Hall, Sheffield, from June 2 to 5, featuring the properties of nickel, nickel-containing materials, the platinum metals, and s.g. iron. The exhibition is divided into sections dealing with mechanical and physical properties, corrosion resistance, electrodeposition, strength at high temperatures, toughness at sub-zero temperatures, and welding. Each day a number of technical films will be shown, including films on welding and corrosion.

CONTRACTS

The Power-Gas Corporation (Australasia) Pty. Ltd., the Australian subsidiary of The Power-Gas Corporation Ltd., of Stockton-on-Tees, has received an order worth £A800,000 for one unit of carburetted water-gas plant from the Australian Gas Light Company for their Mortlake Works, Sydney. The unit, which will have a normal capacity of 9,000,000 cu ft of 550-BTU gas per day, with a peak-load capacity of 12,000,000 cu ft of gas per day, is believed to be the largest single unit of carburetted water-gas plant in the world.

The first order from Australia for an EMIAC II two-module analogue computer has been received by E.M.I. Electronics Ltd., from the Australian Government Aircraft Factory, Melbourne.

A contract has been recently placed by Siemens Edison Swan with the Kestner Evaporator and Engineering Co. Ltd., of London, for a Kestner installation to neutralize the acid effluent from their plating shop.

An order worth £20,000 for public electricity supply transformers has been received from the Electricity Department of the City Council of Singapore by the Gresham Transformer Group, of Twickenham Road, Feltham, Middlesex.

The award of an engineering contract worth $50,000,000 for a refinery at Mersin, Turkey, to the Foster Wheeler Corporation of New York, has been announced by Mobil International Oil Company, a division of Socony Mobil Oil Company, Inc. The refinery, which has a capacity of 65,000 barrels a day, is being built at the request of the Turkish Government by four companies respectively affiliated with the British Petroleum Company, Ltd., California Texas Oil Corporation, Mobil International Oil Company, and the Shell Petroleum Co. Ltd.

Metal Industries announce that their subsidiary, Fawcett Preston & Company, of Bromborough, Cheshire, has received orders for three thermoplastic extruders. One of the machines will go to Pirelli, Buenos Aires, the second to Pirelli, and the third to Cavi Electric, both of Turin. The value of the equipment, which is designed for covering cable with plastic, is about £23,000.

Moxey Limited, of Birmingham, have been awarded a contract by the South Durham Steel & Iron Co. Ltd. for the manufacture and installation of ore handling and grading plant at their West Hartlepool South works.

The United Kingdom Atomic Energy Authority has awarded a contract to Messrs. W. J. Fraser & Co. Ltd., chemical engineering contractors, of Romford, Essex, for the design of a plant for the recovery of radioactive caesium from highly active waste materials produced in the processing of irradiated fuel.

Orders worth nearly £400,000 have been placed by the National Coal Board with The General Electric Company Limited for five winders. They include two winders for the Birch Coppice Colliery, rated at 400 hp and 1490 hp. The other three winders are a 1450-hp machine for Western Colliery, a 1900-hp winder for Caerau Colliery, and another of 1100 hp for Cortonwood.

Two new reinforced-concrete, natural-draught, hyperbolic cooling towers for the Padiham B Power Station, Lancashire, are to be built by the Mitchell Construction Co. Ltd. of Peterborough. Each tower will be 300 ft high with a normal capacity of 3,500,000 gallons per hour. Work on the contract, which was awarded by the Central Electricity Generating Board and is worth £250,000, will begin in May.

A contract for aero-engine turbine blades, worth approximately £100,000, has been received by D. Napier and Son, Ltd., from East Germany.

During the early part of the second world war Britain supplied much of the equipment for the Morgul Copper Mines in Eastern Turkey. For this project Head Wrightson Stockton Forge Ltd. were responsible for providing classifying, grinding, and drying equipment, in addition to a number of copper converters. Financed as part of the American ICA dollar arrangements, large quantities of spares have been despatched to Turkey, and recently Head Wrightson have received orders for equipment amounting to $125,000 from the Turkish Government Agency ETI Bank.

The Supply and Development Department of the Pakistan Government has ordered 912 Bedford diesel bus chassis, delivery of which will start during June, and will be completed by the end of the year. The Khartoum Municipality has ordered 30 Mulliner-bodied buses, to be built on the Bedford passenger chassis—the first Bedford buses to go into operation in the Sudan. Further overseas orders for Bedford bus chassis include 50 units for Egypt, 32 for Malaya, 13 for Barbados, 10 for Mauritius, and 4 for Greece.

Swan, Hunter & Wigham Richardson, Ltd., of Wallsend-on-Tyne, and Vickers-Armstrongs (Shipbuilders) Ltd., of Barrow-in-Furness, will be the first British shipyards to install the British Oxygen-Ferranti computer-controlled gas cutting machine, developed by British Oxygen Gases Ltd., in conjunction with Ferranti Ltd. Both these shipbuilding companies have ordered prototype machines for installation in their yards next year. This computer-controlled machine can be regarded as a major step towards the introduction of automation in shipbuilding.

Bonallack & Sons Limited, of Basildon, Essex, have received, through Marconi's Wireless Telegraph Company, Limited, an order, worth about $500,000, for 56 special vehicle bodies. The order is part of a $3,500,000 U.S. Government contract placed with Marconi's for a mobile microwave communication system. In addition, a contract valued at approximately £150,000 has also been placed by the main contractors, Marconi's Wireless Telegraph Company Limited, with Austinlite Limited, of Crawley, for part of an order awarded by the United States Signal Corps Procurement Centre in Frankfurt for twenty-five duplicate 30-kVA standby-to-mains diesel-electric generating sets, to be mounted in mobile trailers, together with automatic control switchgear cubicles.

NEW MULLARD FACTORY IN LANCASHIRE

Work will commence shortly on the construction of a new factory for Mullard Limited at Simonstone, Lancashire. This factory will produce glass for television tubes which is at present purchased in prefabricated form. The new works are to be built on a 24-acre site adjacent to the existing Mullard tube factory, and it is hoped that production can be started later this year.

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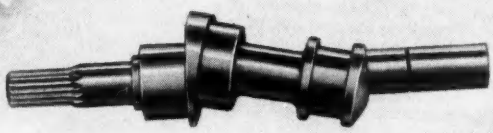

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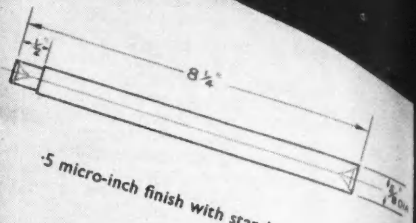

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HEAVY-ENGINEERING SHOP FOR INTERNATIONAL COMBUSTION LIMITED

The new heavy-engineering shop at the Derby Works of International Combustion Limited, opened by the Rt. Hon. Lord Mills, the Minister of Power, on April 24, 1959, enable the company to extend its manufacturing range and diversify its interests in many fields of heavy engineering. The new extension has been so designed that pressure vessels for conventional and nuclear power stations and for the chemical and oil industries can all be manufactured with equal ease. Construction of the new buildings started in January 1958 and was completed last September. Since then, with the co-operation of the contractors, a great number of heavy-engineering machines was installed in a remarkably short period.

The equipment of the new shop includes two 3000-ton vertical presses which can handle heavy plates up to 4 in. in thickness, a large automatic welding machine which can manipulate vessels up to 12·5 ft in diameter and 50 ft in length, a number of heat-treatment furnaces, and other heavy equipment. An adjacent clean-conditions building is designed for the final assembly of heat exchangers and other similar vessels for nuclear power stations and incorporates the most modern equipment in this field. The laboratory and research facilities of the works have also been extended.

SYMPOSIUM ON METAL AND PLASTIC COATINGS

In order to discuss the application of metal- and plastic-coating processes in various industrial fields, the newly formed Metal & Plastic Coatings Association organized a one-day symposium in London on April 17, 1959. The opening lecture was delivered by Dr. T. P. Hoar, of the Department of Metallurgy of Cambridge University, who gave an interesting account of his research work in the technology and metallurgy of metal-spraying processes, emphasizing that, during metal spraying, no melting of the metal, in the ordinary sense, takes place, but that there is, in fact, a special interaction between the base metal and the sprayed coating. Dr. Hoar also referred to his investigations into the corrosion resistance, porosity, and other properties of sprayed-metal coatings after exposure to marine and inland atmospheres, the best coatings being obtained by using a mixture of aluminium and zinc as the spraying material.

The second lecture was given by Dr. L. A. Jordan, director of the Research Association of British Paint, Colour, and Varnish Manufacturers, who stressed the necessity of close contact between metal-spraying and paint industries and expressed the opinion that metal spraying provides the best possible preparation for protective paint finishes.

During the afternoon session, Dr. H. Footner, head of the Paint and Corrosion Section of Shell Petroleum Co. Ltd., dealt with the application of " Epikote " resin-based coatings for protection of pipe lines, tankers, sewage installations, chemical plants, and structural steel work. Finally, Mr. N. Vinson, managing director of Durable Plastics Ltd., analysed the characteristics of various nylon coatings for pipes and instrument holders, and outlined the advantages of PVC coatings for springs and clips.

EXPERIMENTS WITH DRIVERLESS TRUCKS

The Western Region of British Railways is experimenting at Newton Abbot with two driverless trucks. These trucks are being used to convey goods which have been discharged from wagons to chosen points for loading into cartage vehicles for outward delivery.

This new development was initiated twelve months ago by E.M.I. Electronics Limited, who produced a driverless trolley system, known as " Robotug ", and the Western Region of British Railways early recognized the potentialities of this system for use in association with battery-electric platform trucks. Basically, the electronic driving system operates in such a way that it makes a trolley follow a single wire, laid just beneath the flooring and having an alternating current of about 0·5 A with a specified frequency passed through it.

To avoid accidents, a safety bumper is fitted to the front of the truck and, if any obstruction is met, a micro-switch opens the circuit, de-energizes an interlock relay, and halts the trolley. The truck can also be operated in the normal way and driven manually, if required.

The experiments were started on April 7, and will continue for several months to determine the practicability of the new method.

ALUMINIUM-FABRICATING PLANT FOR NEW ZEALAND

As a result of discussions held between the New Zealand Government and the Northern Aluminium Company Limited, construction of a new aluminium-fabricating plant will shortly be started in New Zealand. The new plant will have an initial annual capacity of 5000 tons of aluminium sheet and foil, and 2000 tons of wire and cable for electrical transmission lines. The location of the new plant has yet to be decided, alternative sites in the North and South Islands of New Zealand being under consideration.

INTERNATIONAL CLEAN-AIR CONFERENCE AND EXHIBITION

The International Clean-Air Conference and Exhibition, to be held under the patronage of H.R.H. the Duke of Edinburgh at Seymour Hall, London, from October 20 to 23, 1959, is being organized by the National Society for Clean Air (formerly the Smoke Abatement Society) to celebrate their diamond jubilee. The four-day programme includes sessions on air pollution and related legislation and administration, a reception given by the Lord Mayor and Corporation of the City of London, and visits to research centres and industrial establishments. An open invitation is extended to all in the U.K. to contribute technical or research papers of international interest.

Classified Advertisements

The rate for all classified advertisements is 9d. per word : in bold print 1s. per word : minimum order 10s. Box-number advertisements 1s. extra. Semi-displayed advertisements on this page 60s. per single column inch. Instructions, together with remittance, must be received not later than the 1st of each month for advertisements to appear in the same month's issue.

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NEW 200-TONS PRESS BRAKE. IMMEDIATE DELIVERY, subject to prior sale. Maximum working length 13 ft. 11 in. Between uprights 11 ft. 8 in. Maximum thickness plate handled .47". Steel plate construction. Motor drive. Weight about 25½ tons. An excellent machine. Full details, illustrations, from **F. J. Edwards Limited,** 359, Euston Road, London, N.W.1. or 41, Water Street, Birmingham, 3.

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SIG. 2.

NEW TECHNICAL BOOKS

Metal Products from Holland. 2nd edition, 1958. 765 pages. Copies obtainable gratis from the publishers, Vereniging van Metaal-Industrieën Den Haag, Nassaulaan 13, The Hague, Holland.

During the past twenty years, Holland has developed into an important industrial country, with a metalworking industry which has an extremely large share in the national outcome. It is not surprising, therefore, that there is a demand for a publication surveying the production possibilities of the Dutch metalworking industry, and this comprehensive book, compiled by the Association of Metalworking Industries in The Hague, in which more than 70% of the organized Dutch metalworking industries have been combined, satisfies this demand satisfactorily.

This second edition, well-conceived and neatly produced, gives detailed lists of products, a register of manufacturers, and a comprehensive index. All information is provided in four languages, i.e., French, English, Spanish, and Dutch.

British Instruments, 1959. 615 pages. Published by the Scientific Instrument Manufacturers' Association and United Science Press Limited, Boswell House, 9 Gough Square, Fleet Street, London, E.C.4. Price: 42/-

Providing a complete and up-to-date illustrated directory and buyers' guide, covering all British scientific and industrial instruments and their component parts, this excellent volume combines the information previously available in two separate books, i.e., "British Scientific Instruments", published by the Scientific Instrument Manufacturers' Association, and "The Instrument Directory and Buyers' Guide", published by United Trade Press Ltd.

In addition to comprehensive classified lists of instruments and components, alphabetically arranged announcements of manufacturers, and a glossary in English, French, Spanish, and German, details are given of Associations allied to the instrument industry, relevant British Standards Specifications, manufacturers or prototypes and small batches, selected trade names, and consultants, engineers, and installers of instrumentation schemes.

Theory of Beams. By T. Iwinski. 85 pp., 25 illustrations. Publishers: Pergamon Press, Ltd., 4 & 5 Fitzroy Square, London, W.1. Price: 21/-.

Translated from the original Polish by E. P. Bernat, of the University of Sheffield, this monograph is the first part of a major project on the application of the Laplace Transformation method to static problems in the theory of structures, and deals with beams on two or more supports under various conditions of loading.

In discussing the application of the Laplace Transformation method to the solution of the ordinary differential equations occurring in the theory of beams, all possible types of loading are considered in the case of beams on two supports with various conditions of end-fixing, as well as continuous beams with rigid and elastic supports, In all these cases, it is shown that the elastic curve equation can be expressed in the form $y = W(x) + S(x)$, where both $W(x)$ and $S(x)$ are polynomial functions completely independent from each other. These are defined by the author as step functions and, while the coefficients of the first function depend entirely on the nature of the supports of the beam under consideration and can be evaluated from the known boundary conditions, the form of the second function (called the load function) depends solely on the type of loading of the beam and can be determined beforehand, if the load distribution is known. Thus, the problem of deriving the elastic curve of a beam is reduced simply to that of finding the coefficients of the polynomials, instead of solving differential equations.

The Pump Users' Handbook. By Herbert Addison, O.B.E., M.Sc., M.I.C.E., M.I.Mech.E. 126 pp., 55 illustrations. Publishers: Sir Isaac Pitman & Sons Ltd., Parker Street, Kingsway, London, W.C.2. Price: 30/-.

Compiled on behalf of the British Pump Manufacturers' Association, this useful book is intended to offer aid and guidance to owners and users of pumping plant, and especially to the men in control of this plant, those who choose it, install it, and develop a sympathetic insight into its operation.

Specific chapters have been devoted to the installation and performance of pumping plant and to the diagnosis of such infrequent trouble as may occur. Matters such as cavitation and pressure-surges, complicated though they may be, have also been treated, for it is essential that the facts about these dangers should be made known. For the benefit of those wishing to choose a pump to meet a particular condition, selection charts, based on all possible types of machine, are included and there is also a supplement giving guidance in finding the suppliers of these pumps.

Patents for Engineers. By Laurence H. A. Carr, M.Sc.Tech., M.I.E.E., A.R.P.S., and J. C. Wood, LL.M., 108 pages. Publishers: Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price: 18/-.

Although there are many books for engineers dealing extensively with patents and patent law, there is a requirement for a short work which not only deals with the law in simple terms, eschewing, where possible, irritating legal jargon and irksome detail, but which also deals specially with its engineering and commercial aspects.

This book admirably fulfils these requirements, presenting as it does in simple and readily understandable terms the basic outlines of the law and practice relative to patents and patentable inventions, including concise and pertinent information on registered designs, trademarks, etc. In short, it helps to prevent engineers from taking any step which might later put them in a difficult position, and tends to make any discussions they may have with a legal adviser more fruitful, merely because they will be more likely to know in advance all, or nearly all, of the information they may be required to furnish.

Solution of Problems in Theory of Machines. By S. Anvoner, B.Sc.(Eng.) London, A.M.I.Mech,E. 500 pp. 464 illustrations. Publishers: Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price: 35/-.

This book contains nearly 500 examples, of which more than 200 are fully worked out, and the remainder left as exercises, for which the answers are given. Most of these examples are taken from past examination papers in B.Sc. (Eng.) London, carefully chosen to cover a wide range of topics, and at the beginning of most chapters the relevant formulae are deduced for reference purposes when solving the examples.

Aircraft Electrical Engineering. Edited by G. G. Wakefield, A.M.I.E.E., A.F.R.Ae.S. 364 pp., 201 illustrations. Publishers: Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price: 50/-.

This interesting and authoritative volume, one of the series of textbooks published under the authority of The Royal Aeronautical Society, is based on a number of lectures given at the Imperial College of Science and Technology, London, the majority of the contributors being active members of the aircraft industry.

In addition to chapters devoted to d.c. and a.c. machines, switchgear, aircraft batteries, and electrical power systems and installation engineering, special attention is drawn to environmental conditions and functional requirements, to the nature and physical causes of high-altitude brush wear, and to cooling and vibration problems. System operation and protection is also discussed, and a survey of future trends and requirements is included.

The Teddington Gauging system has inherent advantages which provide fast, positive, trouble-free measurement combined with extreme accuracy.
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1. Malleablizing Furnaces. Ensuring uniform temperature distribution at all stages of the heating, soaking, and cooling cycle, a series of oil-fired malleablizing furnaces described in a 6-page leaflet is claimed to have the advantage of a simple control system, in which fuel flow is controlled by a positive-displacement pump and single controls are used for secondary air and furnace pressure. In addition, these furnaces are provided with a single burner with no moving parts.

2. Electric Cranes. An illustrated 20-page brochure describes a wide variety of electric cranes, including grabbing and steelworks cranes, long- or short-span goliath cranes, and cranes for heavy and special duties. All gears and runner wheels of these cranes revolve on high-grade precision ball or roller bearings, which are claimed to give, under normal conditions, a lifetime service with practically no wear. Tables of weights, dimensions, and wheel loads for various spans are given, as well as recommendations for selection, maintenance, and operation.

3. Metal Sinterings. Excellently produced and illustrated in colour, a 32-page booklet serves as a useful guide to the application of metal sinterings in industry. In addition to a description of the metal sintering process, the advantages, design principles, and lubrication of metal sinterings are outlined. Furthermore, physical properties of a number of sinterings, including oil-retaining bearing materials, high-duty bearing materials, high-magnetic-permeability materials, and structural materials are given.

4. Hydraulic Press Brakes. A range of hydraulic press brakes in capacities from 23 to 220 tons is described in a 4-page leaflet. These machines can also be regarded as hydraulic presses since, in addition to bending, they can be used for cambering, cutting-out, precision-rectification, and punching operations. Robust construction, silent operation, flexibility, and accuracy and reliability of setting, are some of the features of the presses which are provided with a number of interchangeable standard tools, and are claimed to ensure a high rate of output.

5. Leakproof Gate Valves. Specially designed to overcome the inherent disadvantages of conventional gate valves, the range of leakproof gate valves described in this illustrated 6-page leaflet includes stainless-steel valves for chemical service and carbon-steel valves with stainless trim for service in the oil industry. In these new valves, in addition to the metal-to-metal fit of the wedge against the valve seats, two fluon seals are provided, which are compressed against the wedge as it is lowered, eliminating the need for a double block and bleeder in piping installations, and providing an impenetrable shut-off.

6. Portable Welding Kit. Requiring no installation apart from connecting to the selected mains voltage, the portable welding kit, presented in a 12-page brochure, is primarily designed for the repair of light-gauge stainless-steel components. However, it may equally well be used for other light-gauge fabrications. A complete set of working tools is supplied with these units, which are manufactured to withstand all climatic conditions and require practically no maintenance.

7. Boltless Doors or Covers for Pressure or Vacuum Vessels. Ideally suited for covering sterilizers, strippers, vulcanizers, impregnating autoclaves, and testing, pressure, and vacuum vessels, new types of boltless doors or covers are presented in an illustrated 8-page brochure. Closing or opening of these doors is carried out by rotating a specially constructed ring clamp over a short distance, which operation may be accomplished manually, by an electric motor, by compressed air or hydraulically. In addition, for vessels subject to steam or air pressures a safety device in the form of electrically operated bars is provided.

8. Monel Nails. The monel nails described in a 4-page leaflet are so designed that, when driven into wood, grooves in the nail shape the wood fibres into scores of tiny wedges which grip the fastening so tightly that vibration cannot shake it loose. Applications of these nails include boat building, cooling towers, flooring, fume hoods, metal sheathing, metal linings, wooden fencing, etc.

9. Micron Filter Unit. Designed to meet the need for highly efficient filtration of fluid for precision hydraulic components, a micron filter unit is presented in a 4-page leaflet. Two models are at present available for operation in systems up to 2000 psi, one for direct line filtration, and the other for integral mounting with a servo-valve, but models for use at pressures up to 3000 psi can also be supplied.

10. Expanded Metal, Lathing, and Electrically Welded Steel Meshes. A 12-page brochure gives particulars of expanded metals and lathing manufactured from mild-steel plates and sheets, the application of which includes grills, machine guards, shields, refuse collectors, screens, and the casing of reinforced concrete beams and stanchions. A supplementary 8-page brochure presents a range of electrically welded steel meshes for concrete reinforcement and various other applications, including fire screens, guards, industrial stacking, crates, and mechanical-handling pallets.

11. Air Power Cylinders and Pneumatic Equipment. The range of air power and pneumatic equipment described in an illustrated 24-page booklet includes various types of air hoists, air control valves, and special-purpose air power cylinders. Ease of manipulation, safety in use, long service life, and ease of maintenance are the main advantages of these units, standard sizes and other details of which are given in this booklet. Two supplementary brochures contain descriptions of air power valves and give examples of pneumatic circuits and valve gears, including circuits with push-button control and automatic sequence control.

12. Hydraulic Actuators. An illustrated 12-page brochure contains particulars of hydraulic actuators, which give a positive two-way action relative to the load applied when built into an appropriate hydraulic circuit. They can be used as a means of putting pressure into a hydraulic circuit, as well as for converting pressure into motive power. The units are rust-proof, vibration-proof, permanently self-lubricating, provision being made for temperature compensation.

13. High-Speed Rotary Switches. The high-speed rotary switches described in a 2-page data sheet find many uses in remotely operated systems, d.c. signal chopping, waveform generation, amplifier stabilization, low-level sampling of strain-gauge and thermocouple signals, etc. The construction of the switch permits it to be one of the smallest of its kind, and particular care has been taken to extend its life without maintenance.

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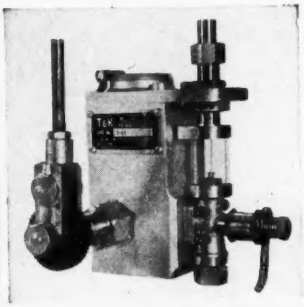

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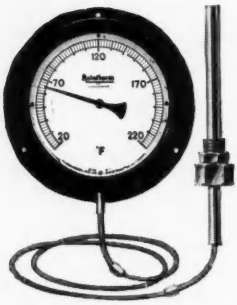

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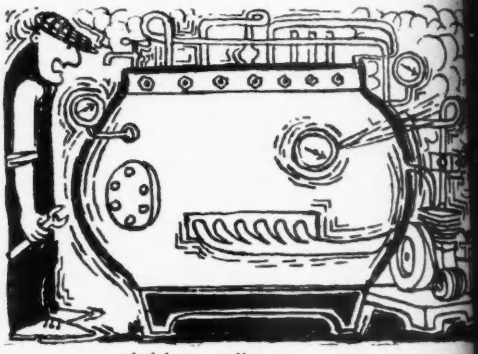

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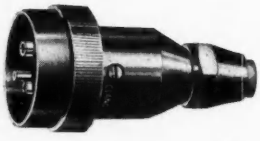

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